OBSERVATIONS
AND
EXPERIMENTS
For inveſtigating the
CHYMICAL HISTORY
OF THE
Tepid SPRINGS of BUXTON;

1327

TOGETHER WITH

An Account of ſome newly-diſcovered, or little known Properties of Subſtances relating to ſeveral Branches of CHYMISTRY, and ANIMAL and VEGETABLE LIFE;

TO WHICH ARE PREFIXED,

A CHRONOLOGICAL RELATION OF THE USE OF BUXTON-WATER FROM THE EARLIEST RECORDS TO THE PRESENT TIME, SKETCHES OF A HISTORY OF THE ATMOSPHERE OF THE PEAKE, AND OF THE EXTERNAL FORM AND INTERNAL STRUCTURE OF THE MOUNTAINOUS REGIONS OF DERBYSHIRE:

INTENDED FOR THE

Improvement of Natural SCIENCE and the Art of PHYSIC;

In TWO VOLUMES.

VOL. II.

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LONDON:

PRINTED FOR J. JOHNSON, ST. PAUL'S CHURCH-YARD.

MDCCLXXXIV.

PART

CONTAINING

EXPERIMENTS and OBSERVATIONS

ON THE

Permanent Vapour that arises spontaneously

FROM THE

TEPID SPRINGS OF BUXTON.

To which are prefixed,

An Account of the received Opinions concerning the Nature of the volatile Part of medicated Waters;

AND

A Narrative of the Discovery of the Error in the received Opinion concerning the Nature of this permanent Vapour of BUXTON-WATER.

THE apparently permanent Vapour, that arises spontaneously from the tepid Waters of Buxton, in Form of Bubbles, described Vol. I. p. 152, 153, is a Property too obvious to escape the Notice of the most careless Observer. Accordingly, Dr. Short repeatedly mentions this Appearance in these Springs more than 50 Years ago; but, making no Observations or Experi-

ments to discover the Properties of the Matter composing the Bubbles, he concluded it was *Air*; a Matter which will appear no wise surprizing when we consider the State of natural History in his Time, for this was the only Substance which was then known to produce that Appearance. And as this Water had medicinal Effects not to be accounted for from an Impregnation with any other Substance, they were referred to this *Air*, as it was termed, and to a *sulphureous Halitus*, or a *most subtile* and *impalpable Sulphur*, in a *mineral Steam*, *Vapour*, or *Spirit*, that was conjectured to be contained in this Water; but whether as a Part of the Air or Substance composing the Bubbles, or as a separate Vapour, is not clear from this Author's Description.

As natural History improved, it was discovered, that *Air* was not the only Species of Substance in Nature that was a permanent Vapour, and might enter into the Composition and exhibit this Appearance of *Bubbles* in Water; and by this Impregnation, render Springs medicinal. For Dr. Brownrigg conjectured, that the subterraneous Vapours called *Damps*, and *mineral mephitic Exhalations*, probably impregnated Waters whose medicinal Powers were referable to, or the Efficacy of which resided in, a certain subtile and volatile - Principle denominated *Spirit*. This Conjecture was suggested by the Consideration

that these subterraneous Vapours were known to produce great Effects on human Health and Life. And the ingenious Proposer of this Supposition was actually believed to have demonstrated *one* of these subterraneous Vapours or Damps in the *Pyrmont* and *Spaw-Waters*; because he obtained from these Springs a permanent Vapour that suffocated Animals, and extinguished Flame; and which, therefore, was concluded to be the same Substance as the *Choke-Damp* of the English Miners (*a*), on which depend the acidulous Taste, sparkling Appearance, and medicinal Qualities of these Springs; and which was also believed to be the same Substance as the *Mephitis* (*b*) of the Ancients, or *Mofette* of the modern Italians, and the well-known *Gas Sylvestre* of Van Helmont; one Species of which, was a permanent Vapour arising during the vinous Fermentation.

The illustrious Professor of Chymistry at Edinburgh, afterwards demonstrated (*c*) by the most decisive and accurate Experiments, that calca-

(*a*) *Phil. Trans.* Vol. LV. p. 236. and Vol. LXIV. P. ii. p. 359.

(*b*) ——————— Lucosque subalta
Consulit Albunea; nemorum quæ maxima sacro
Fonte sonat, sævamque exhalat opaca *Mephitim.*
VIRG. ÆN. Lib. VII.

(*c*) *Essays and Observations physical and literary* of Edin. Vol. II. Article viii. p. 172.

reous Earth was composed of Quicklime and a Substance that he named *fixed Air*; and that Quicklime might be restored to the State of calcareous Earth by combining it with this Substance.

It was shewn soon after this Discovery, that *Fixed Air*, of late more properly called *Gas*, the Appellation bestowed on it by the Person who first discovered it, separated from calcareous Earth, was a permanent Vapour:—that it extinguished Flame, and also animal Life, either by its sedative Power upon the nervous System, or by its stimulant Quality when applied to the Lungs:—that it precipitated Lime from Lime-Water by uniting with the Quicklime dissolved therein:—that it combined with Water, rendered it acidulous, and gave it a sparkling Appearance:—that when either added separately, or combined with Water, to Lime-Water, it rendered it milky; which on standing, deposited Sediment, supposed to consist of the Quicklime restored to the State of calcareous Earth by its Combination with Gas.

These Properties of Gas being discovered, it was affirmed, and seemingly on good Grounds, that the volatile medicinal Substance, contained in the *Acidulæ* in general, and the Springs of Spaw and Pyrmont-Water in particular, was that permanent Vapour which is a constituent or elementary Part of calcareous Earth. Physicians,

however,

however, were not content with accounting for the particular chymical Properties and medicinal Effects of the *Acidulæ* on the Principle of Gas, but they unwarrantably concluded, that all medicinal Springs containing a volatile Principle, real or fictitious, that was apt to escape on Exposure to the Atmosphere, owed their Virtues in the Cure of Diseases to Gas. Nay, so general was the Opinion that the Efficacy of a medicinal Spring resided in this permanent Vapour, that on no better Grounds than a Head-ach or Giddiness, or that Degree of Intoxication which is often the Consequence of drinking Spring-Water, and its precipitating Lime from Lime-Water, it was pronounced, that such a Water was possest of its particular Power in Diseases, in Consequence of the Gas contained therein; especially if it did not appear to be impregnated with any solid Substances which might account for its medicinal Effects.

It is hardly necessary to observe, that such an Opinion was very ill-founded, because it was not demonstrated that the volatile Substance above-mentioned was Gas, or even that it did exist in the Water; and that a Head-ach or Giddiness were peculiar Effects of this permanent Vapour impregnating Water; or, admitting the Precipitation with Lime-Water to be occasioned by Gas, that this Substance was in Quantity sufficient to justify the Conclusion. It was owing, most pro-

bably, to the Influence of this prevailing Opinion, that many ingenious and learned Writers have been led into the Error of referring the principal medical Properties of *Bath warm Waters* (*d*), and

(*d*) Dr. *Falconer on Bath-Waters*, Vol. I. Ch. iv. p. 322, 324, 328.

The Evidences of Gas in theſe Waters on which this celebrated Author grounds his Application and Explanation of the Effects of *Bath-Waters* are related p. 228. "This (viz. *fixible Air*) is diſcoverable by the ſparkling Appearance, pungent Taſte and Smell, and intoxicating Effects of the Waters that contain it; they likewiſe precipitate Lime from Lime-Water on Admixture with the latter, and corrode and even diſſolve Iron when freſh taken up, though they loſe both theſe Qualities on ſtanding ſome Time expoſed to the Air. The Air likewiſe conveyed from theſe Waters by a bended Tube on the Surface of a Quantity of Lime-Water will precipitate the Lime from it."

The only deciſive or peculiar Property here related of Gas is its Effects on Lime-Water, and its loſing the Power of producing this Effect by Expoſure to the Atmoſphere. But as there are few Springs that do not precipitate Lime from Lime-Water, and as merely a Film was produced by the Steam of freſh drawn *Bath-Water*, conveyed to Lime-Water, which happens on mere Expoſure of Lime-Water to the Atmoſphere, theſe Effects are not Proofs of a Quantity of this permanent Vapour greater than in ordinary Springs. I wiſh the ingenious Author would repeat the Experiment of mixing Lime-Water with *Bath-Water* that has been ſome Time expoſed to the Atmoſphere, for it is very extraordinary that this Water ſhould part with its Gas by mere Expoſure to the Atmoſphere, ſo as no longer to precipitate Lime in Lime-Water becauſe it is chymically combined with the Water, and ſince Dr. Prieſtley found it required a boiling Heat for ſeveral Hours to expel this permanent

and *Matlock* and *Buxton tepid Springs*, to Gas (*e*), as well as of many other medicated Waters.

The

manent Vapour from Bath-Water. But if these Remarks be not sufficient to convince the Reader that the Efficacy of *Bath-Water* was erroneously referred to Gas, the following Experiment affords a convincing Proof of this Mistake.—From a Pint of *Bath-Water*, by boiling four Hours, Dr. Priestley obtained Air which was about one-thirtieth of the Bulk of the Water, and about one-half of it was Gas. The Residuum appeared by the Test of nitrous Air to be rather better than Air in which a Candle had burned out.

On this Experiment this Philosopher founded the following Opinion, to which I beg Leave to subscribe. "The Quantity of fixed Air, that appears by this Experiment to be contained in the Bath-Waters, is so very small, that I think it very improbable that their Virtues should be at all owing to it. Few Spring-Waters, I believe, contain much less fixed Air, and many I know, which have no medicinal Virtue at all, contain more. The Pump-Water belonging to the House in which I now live contains about one-fourteenth of its Bulk of fixed Air, and it may be seen in my former Volume, page 160, that my Pump-Water at Leeds contained about one-fiftieth of its Bulk of Air of the very same Composition as the Air of the Bath-Waters, viz. half of it fixed Air, and half common Air a little phlogisticated; so as to be in about the same State as Air in which a Candle had burned out."—Exper. and Obs. Vol. II. p. 223.

(*e*) Dr. *Percival*, see Vol. I. of Dr. *Priestley*'s *Exper. and Obs. on different Kinds of Air*, says: "In a Course of Experiments, which is yet unfinished, I have had frequent Opportunities of observing, that fixed Air may in no inconsiderable Quantity be breathed without Danger or Uneasiness. And it is a Confirmation of this Conclusion that at Bath where the Waters copiously exhale this mineral Spirit the

The Negligence of Phyſicians to inveſtigate the Grounds on which they practiſed was the more reprehenſible, on Account of the Inſtruction they might have obtained, from the Addition which in modern Times has been made to the Stock of natural Hiſtory, in particular to the Hiſtory of permanent Vapours; by which it was ſhewn, that there were ſeveral other permanent Vapours produced by Art, and probably exiſted in Nature, beſides *Air*, *Gas*, and the *Fire-Damp* of the Miners, or *Oil of Metals* of the Chymiſts; and that of all theſe Subſtances not one could be applied to the Lungs of Animals without ſuffocating them, or was capable of ſupporting Flame or Inflammation, excepting *Air*. Therefore, although the Concluſion of that ſagacious Obſerver, who firſt exhibited in a ſeparate State (*f*) the

Bathers inſpire it with Impunity; *at Buxton alſo where the Bath is in a cloſe Vault the Effects of ſuch Effluvia if noxious muſt certainly be perceived.*"

(*f*) It is probable we are indebted to Dr. *Brownrigg* for being a principal Means of rectifying the Error of Sir Iſaac Newton, Boyle, and Hales, who had met with ſeveral Species of permanent Vapour lately demonſtrated, yet did not diſtinguiſh them from Air; but ſuppoſed their not ſupporting animal Life and Flame was owing to ſomething mixed with Air, as an extraneous Matter, and not that they were Subſtances as diſtinct from Air as Oil from Water, or any two Subſtances in Nature. As a Juſtification of this Remark I ſhall cite the following Paragraph from Dr. Hales's excellent Works. "As to the noxious Quality of theſe factitious Airs,

the *volatile Spirit of Springs*, and ſhewed that *Air* was not the only permanent Vapour in Nature, was, conſidering the limited Power of the beſt Exertions of the human Mind, as juſt as could be expected when he advanced, that as the permanent Vapour of Spaw-Water ſuffocated Animals, and extinguiſhed Flame, it was the ſame Subſtance as the Choke-Damp in Mines, and mephitic Exhalations of certain Caverns, Fiſſures of the Earth, and Lakes; yet after ſo many Properties of Gas alone, and of this Subſtance combined and mixed with Water, had been diſcovered; and Dr. *Rutherford* (*g*), Dr. *Prieſtley*, and ſome

Airs, whether they are made by Fermentation, Efferveſcence, or Diſtillation, there cannot reaſonably be an Objection againſt their being *true Air*; becauſe it is well known that common Air is frequently alſo impregnated with moſt noxious and deadly Vapours. That the Flames which aſcend up in the Air from fermenting Wines are very pernicious, thoſe alſo from burning Brimſtone are moſt deadly, and ſuch Mr. Hawkſbee found the common Air which paſſed through heated Iron and Braſs Tubes; but the Air which paſſed through heated Glaſs Tubes was not noxious; an Argument that the Vapours which ariſe from the Iron and Braſs were noxious and not the hot Air." In theſe Experiments Dr. Hales produced ſeveral diſtinct Species of permanent Vapour diſtinguiſhed now-a-days, and termed *Gas*, *phlogiſticated Air* or *Compound of Air and Phlogiſton*, *Gas Sylveſtre*, and perhaps others.

(*g*) Aër ſalubris & purus Reſpiratione Animali non modo ex Parte fit Mephiticus ſed aliam Indolis ſuæ mutationem ſingularem inde patitur. Poſtquam enim omnis Aër Mephiticus

ſome others, had clearly diſtinguiſhed *Gas* from another Species of permanent Vapour, called *phlogiſticated Air*; a Subſtance formed, or ſuppoſed to be formed, by the Union of Phlogiſton with Air; which two Subſtances had been for ſome Time before not apprehended to be different Things; and that from the natural Hiſtory of the Earth, we might have expected to meet with Air united with Phlogiſton much more frequently than with Gas; I ſay, was it not ſurprizing, that Practitioners ſo inſtructed ſhould not have been

ticus ex eo, ope Lixivii Cauſtici, ſecretus & abductus fuerit, qui tamen reſtat nullo modo ſalubrior inde evadit, nam quamvis nullam ex Aqua Calcis Precipitationem faciat, haud minus quam antea & Flammam, & Vitam extinguit — — — — — — — — — — — — — — — — —

— — Siculi Vita Animalium à libero aëris uſu pendet, ita hic omnino neceſſarius eſt ad Flammam Ignemque alendum. Sed nec Minus ab Igne, quam à Reſpiratione tranſmutatur in Indolem utrique Uſui ineptam & contrariam. Et quoniam effectus prorſus ſimiles ſunt, quæ prius de Reſpiratione protuli de Inflammatione repeti queant.

After obſerving that the Gas found in Receivers of Air in which Animals have died, or Subſtances burnt, is rather extricated from the Veſſels of the Animal by breathing, and from the inflammable Body by burning, than is a Subſtance formed by Reſpiration or Combuſtion, from the Phenomena of the Inflammation of Phoſphorus and Calcination of Metals in Receivers of Air the Concluſion is this: That *the Air in the Receivers after Inflammation and Reſpiration is atmoſpheric Air united to, or, as it were, ſaturated with Phlogiſton.*— See *Diſſertatio Inauguralis de Aëre fixo dicto aut Mephitico. Edinburgh,* 1772.

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led to enquire, whether *the Compound of Air and Phlogiston* impregnated Springs more frequently, or as often as Gas. Had this Idea been as generally entertained as the Opinion that the volatile Part of medicinal Waters was Gas, the Nature of that Vapour which arises spontaneously from Bath warm Springs had not been mistaken for Gas (*b*); and before this Time, Physicians would have

(*b*) Doctor Priestley, with his accustomed Sagacity, detected a few Years ago the Error concerning the Nature of a Vapour with which the warm Waters of Bath abound. This Philosopher, speaking of Bath-Water in the second Vol. of his Exp. and Obs. on Air, p. 224, says, " besides the Air contained in the Bath-Water there is a considerable Quantity of Air continually bubbling up from almost every Part of the Soil through the Water in the Bath. When I was about to examine this Air, Dr. Falconer informed me that it had been done already by Dr. Nooth, and that an Account of his Experiments was inserted in the second Volume of his Treatise on the Bath-Waters: " At the Place where the Springs rise in the Baths numerous Bubbles of Air are observed to ascend along with them. A Quantity of Air of this Kind was collected at the King's Bath by inverting a Glass and holding it over the Bubbles as they rose and then conveying it in an inverted Bottle, which when full was carefully corked up and carried away. The Air thus obtained answered in every Respect to fixible Air precipitating Lime in Lime-Waters, and having every other Quality which that Substance possesses."—*Falconer on Bath-Waters.*

" Being informed of this I thought it unnecessary to re-" peat the Experiment, but finding upon Enquiry that " Dr. Nooth had not examined what Proportion the Resi-" duum of the fixed Air bore to the Whole, or of what Qua-" lity

have founded their Opinions of the Nature of the permanent Vapour that escapes of its own Accord from the tepid Springs of Buxton, on Observations and Experiments made to determine its Properties.

Since Dr. Priestley detected a few Years ago what he calls *phlogisticated Air* in *Pump-Water* and in the warm Springs at *Bath*, a permanent Vapour which was unfit for Respiration and Inflammation, a Substance probably possessing these negative Properties has been found in small Quantity by another Author in Scarborough-

" lity that Residuum was, though he speaks of the Whole " as containing every Quality of fixed Air, I thought it " would not be amiss as I was upon the Spot to make the " Trial myself. Accordingly I took about a Pint of that " Air in nearly the same Manner that Dr. Nooth had done, " and found upon Examination that only about one-twentieth " of its Bulk was fixed Air precipitating Lime in Lime-Wa- " ter and being readily absorbed by Water. The rest ex- " tinguished a Candle, and was so far phlogisticated that two " Measures of it and one of nitrous Air occupied the Space " of $2\frac{19}{20}$ of a Measure, that is, it was almost perfectly " noxious."

It is very extraordinary that this permanent Vapour, called *phlogisticated Air*, of Bath-Water should have escaped the Notice of Dr. Higgins who does not mention this Substance in his Analysis of this Water published May 30, 1780.

The permanent Vapours found by this Gentleman in a Winchester Gallon of *Bath-Water* were, 12 Ounce Measures of acidulous Gas, (fixed Air) beyond the Quantity retained by the calcareous Earth in the Heat of boiling Water, and two Ounce Measures of atmospheric Air.

Water and Sea-Water (*i*); ſo that it is now hoped Obſervers will direct their Enquiries to other permanent Vapours in Springs that are not reſpirable as well as to Gas, which has hitherto almoſt entirely occupied their Attention.

I do not pretend that I entertained a Conjecture excited by any Part of natural Hiſtory already known, or in particular by the Detection of the Error diſcovered in the Opinion of the Kind of Vapour that ſpontaneouſly eſcapes from *Bath-Water*, that Spring-Waters in general were as often impregnated with *the Compound of Air and Phlogiſton*, or other permanent Vapours incapable of ſerving for Reſpiration, as Gas; and therefore was led to examine more particularly the Evidences of the univerſal Belief, that the apparently permanent Vapour that riſes of its own Accord from Buxton-Water, p. 152, 153, Vol. I. was Gas; for ſuch was my Ignorance and want of Sagacity, that during a Reſidence of two or three Weeks at Buxton the latter End of the Summer 1781, although I was employed in Obſervation, I did not entertain a Suſpicion of the Truth of the prevailing Opinion concerning the efficacious Subſtance and volatile Part of theſe tepid Springs. I did not then know of any permanent Vapour excepting Gas of Effi-

(*i*) According to Dr. *Higgins* a Wincheſter Gallon of *Scarborough-Water* contains about four Ounce Meaſures of *phlogiſticated Air*, and the ſame Quantity of *Sea-Water* contains about one Ounce Meaſure of this permanent Vapour.

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cacy in Waters in general; and, my Attention being almoſt wholly employed in learning the medicinal Effects of theſe Springs by immerſing healthy Bodies therein, I did not queſtion the Evidences given, that Gas was the efficacious Matter in Buxton-Water. Theſe Proofs were, the Abundance of Bubbles in the Bath; the Giddineſs or Head-Ach ſo commonly occaſioned by drinking it; its precipitating Lime from Lime-Water; its Depoſition of calcareous Earth during boiling; and the Want of any other Impregnation to account for its Effects, together with the Information I received, that the Bubbles which ſeparate themſelves from the Bath had been collected by more than one Perſon, and had been indubitably ſhown to be Portions of Gas; in as much as, among other Effects of which I could procure no authentic Account, they ſtifled Animals and extinguiſhed Flame. It was the Event of ſome Experiments in the Courſe of the Winter following, particularly the Diſcovery of the Miſtake in the *Occaſion* aſſigned for the Precipitation of Earth in boiling Water; and that to the Teſt of Lime-Water a Parcel of Buxton-Water, which had been ſo preſerved as to prevent any Gas from eſcaping, contained leſs Gas than common Pump-Water; that induced me to queſtion the Foundation of the Opinion univerſally aſſented to concerning the Nature of the permanent Vapour that ariſes of itſelf from Buxton-Water.

Water. The Judgment I formed was, that the above were but equivocal Proofs of the Truth of the received Opinion. The Reflection that this Water had not the leaſt acidulous Taſte, which muſt have been the Caſe had this Water been highly impregnated with Gas (becauſe before Gas can ſeparate itſelf ſpontaneouſly from Springs they muſt be ſo fully ſaturated therewith as not to diſſolve, or retain in a State of Mixture any additional Portion of this Subſtance) was a ſingle but poſitive Proof that the permanent Vapour which eſcapes ſpontaneouſly from Buxton-Water was not Gas.

By theſe Conſiderations my Curioſity became ſo far excited as to induce me to make an Excurſion the Beginning of February 1782, in Order to learn, whether the Bubbles that eſcaped in ſuch Abundance from the Bath at Buxton were Gas, according to the received Opinion.

I communicated on my Arrival at Buxton the Intention of my Viſit to Mr. Buxton, the ſenſible and worthy Surgeon and Apothecary of that Place, who with his uſual Readineſs and Politeneſs lent me his Aſſiſtance; without which I could not have accompliſhed the Object of my Expedition. This Gentleman however, previouſly to any Experiment, told me the Subſtance I was about to examine had been repeatedly tried, and that it had been declared univerſally, there was no Room for harbouring a Doubt of its being Gas.

 Before

Before relating my Experiments I ſhall obſerve, that a Tube filled to a certain Height with the Bubbles of Buxton Bath-Water while the open End of it was juſt below the Surface of the Bath, being immerged deeper in the Bath the Water roſe within it in Proportion to the Depth to which it was immerſed, and deſcended to the ſame Place as before Immerſion upon raiſing this Inſtrument ſo that the open End was only juſt below the Surface of the Water. Alſo, when the Tube was filled to a certain Mark with theſe Bubbles of Vapour, upon ſtopping the open End ſo that Part of the Finger was puſhed within the Tube, the Water roſe above the Mark; and upon withdrawing the Finger while the Inſtrument remained in the ſame Depth of Water, the Water within it deſcended to the Mark as before; from which I inferred, that theſe Bubbles were a *compreſſible, elaſtic* Subſtance. As it alſo preſerved its Form of Vapour after Expoſure to the Atmoſphere in very cold Weather, by which it was contracted in its Dimenſions, it was concluded be a *permanent Vapour*.

Exper. I. Having collected, in the manner hereafter mentioned, about a Pint Jar quite full of the Bubbles that ariſe ſpontaneouſly from Buxton-Water, p. 24, and ſet it to ſtand inverted in a waſh Baſin brimfull of Water, it was drawn over the Edge of this Veſſel ſo as to admit the Introduction of a lighted Wax-Taper. The Flame of this Subſtance

ſtance was extinguiſhed the Inſtant it was receiv-ed within this inverted Jar filled with theſe Bub-bles; but upon being introduced within this Jar filled with common Air, under this Circumſtance, it continued to flame for ſeveral Seconds of Time. This Experiment was repeated ſeveral Times with the ſame Event.

The above Experiment proved, that the *Mat-ter of theſe Bubbles is not either wholly, or in Part, Air.*

Exper. II. To two Meaſures of theſe Bubbles was conveyed one Meaſure of nitrous Gas, in the uſual Manner, through a Quantity of Water, and agitated in a Phial; no apparent Diminution of Bulk, turbid Appearance, or Colour were pro-duced by this Mixture; nor did the Mixture meaſure leſs than three Meaſures, if the Tem-perature and Breſſure upon the Mixture when meaſured was the ſame as the Heat and Preſſure to which the two Subſtances were expoſed ſepa-rately before they were mixt together. The ſame Event, or nearly the ſame, followed a Repetition of this Experiment; there being always rather more or ſomewhat leſs than, or preciſely three Meaſures of Mixture.

This Experiment ſhowed, that this permanent Vapour *did not contain any Air,* according to the Teſt here employed, and further, that it is wholly unfit for Reſpiration; becauſe no permanent Va-pour is at all capable of ſupporting Life that does

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not diminiſh more or leſs on Mixture with nitrous Gas.

There being no Diminution in Bulk of the permanent Vapour in transferring it through Water in this Experiment, is a Circumſtance which alſo affords a very probable Argument that it is not Gas.

Exper. III. A Phial was filled quite full of theſe Bubbles, and conveyed well corked into a large Baſin of common Pump-Water, in which while in an inverted Poſition the Cork was withdrawn. This Bottle was agitated ſome Time in the Water; by which Means Water roſe rather above the Neck of the Phial, but no higher even after ſtanding a whole Night.

A Phial filled with Gas ſeparated from calcareous Earth by Marine Acid, treated in the above Manner in leſs than an Hour was nearly full of Water. Alſo a Phial filled with Gas was inverted in the Bath and there agitated, by which Means it was ſoon filled with Water.

From this Experiment it may be inferred, that this permanent Vapour of Buxton-Water is *not either wholly or in Part, Gas*; for the Diminution of Bulk that appeared by the riſing of Water rather above the Neck of the Bottle was occaſioned by the Contraction enſuing upon removing a Phial of warm permanent Vapour into a colder Medium than before.

The ſpeedy Combination of Buxton-Bath-Water with the Gas in the inverted Phial ſhews, that

Buxton-

Buxton-Bath either contains no Gas, or that it is not ſaturated with this Subſtance; therefore *the Vapour which eſcapes from it in the Form of Bubbles is not Gas.*

Exper. IV. A Phial immediately after being filled with the *Bubbles that ariſe ſpontaneouſly from this tepid Spring*, was inverted in a Baſin of Lime-Water of the Temperature of 56°. Water roſe within this Phial in about the ſame Quantity as in the former Experiment, and advanced but a very little higher after agitating the Phial and leaving it to ſtand inverted in Lime-Water a whole Night.

A Phial, of the ſame Size as the former, filled with *Gas*, procured by decompoſing Chalk, was agitated in an inverted Poſition in a Baſin of *Lime-Water*; by which Means in a few Minutes the Bottle was almoſt entirely filled with a milky Fluid.

I make the ſame Concluſion from this as from the laſt Experiment. No Difference in the Reſult of it has occurred on repeated Trials, excepting what was occaſioned by the Expanſion or Contraction of the Bulk of this permanent Vapour of Buxton-Water by the different Temperatures of Lime-Water into which it was conveyed; and by the Difference of Preſſure to which it was expoſed.

Mr. Buxton who was preſent during theſe four Experiments, acknowledged they convinced him that the Opinion that this permanent Vapour was Gas was erroneous.

Having ſatisfied myſelf that this permanent Vapour of Buxton-Water was not Gas, inflamma-

ble Vapour, or Air, I propoſed to inveſtigate its other Properties on future Occaſions. I therefore contented myſelf during this Viſit, with procuring ſeveral Quart Bottles full of this Subſtance. It was prevented from communicating with the Atmoſphere by a ſmall Quantity of Water left within the Neck of each Bottle between the Cork and the included Vapour, by tying wet Bladders over the Corks, and preſerving the Bottles inverted.

After this Time I found that a permanent Vapour, which had been miſtaken for Gas, ariſes ſpontaneouſly from *Bath warm Water*, ſee Notes, p. 11, of this Vol. and poſſeſſes ſeveral of the Proties above-related of this permanent Vapour of Buxton-Water; but ſo very few of its Qualities have been inveſtigated that we can only conclude it is not Gas or inflammable Vapour; whether it be of the ſame Kind as this permanent Vapour of Buxton-Water or of a different Species, is to be determined by future Enquiries. This Account, however, afforded me peculiar Satisfaction, becauſe I conſidered it to be a Sort of Teſt of the Truth of my own Obſervations. Hence, although to the beſt of my Knowledge I was the firſt Perſon that ſuſpected and ſhewed by Experiments, that the permanent Vapour which parts of itſelf from the *tepid Water of Buxton* was not Gas, I have no Pretenſions to being the firſt who diſcovered, probably, if not the ſame Subſtance,

certainly a permanent Vapour that was not Gas, or permanent inflammable Vapour in the *warm Springs of Bath*; which had been, as well as the permanent Vapour of Buxton-Water, confidentially believed to be Gas.

During a Reſidence of ſeveral Weeks at Buxton in Auguſt and September 1782, the Summer after I had made the above the Experiments to ſhew that the permanent Vapour with which Buxton-Water abounds is not Gas, I availed myſelf particularly of that Opportunity to inveſtigate the chymical Hiſtory in general of theſe celebrated medicated Springs. The Reſult of this Enquiry, together with my Experiments and Obſervations in Conſequence of my Excurſion the preceding Winter, is ſubmitted in this Work to the Conſideration and Uſe of the Public.

I ſhall now relate the Progreſs I have made in the Knowledge of the natural Hiſtory of the permanent Vapour which extricates itſelf ſpontaneouſly from the Bath at Buxton.

Obſervation. Having attended to the Appearance of the Bath after the Water within it had been entirely let off to the Time of its being filled, a probable Explanation, as I conceived, occurred of the Appearance of the Bubbles as they ariſe from, and are contained in the Bath. See Vol. I. p. 152, 153.

The Streams or Cluſters of Bubbles did not appear when the Bath was nearly empty, except-

ing in a few Places, and in theſe in ſmaller Quantities than when the Bath was full. They not only roſe through the Seams of the Pavement, and Fiſſures in the Rock through which the Springs flow into the Bath, but from various other Vacuities between the Stones of the Pavement through which no Water flows.

Theſe tepid Springs contain a Quantity of the permanent Vapour which forms theſe Bubbles, merely by Means of *Preſſure* and *Adheſion*; either becauſe the Water does not diſſolve it, or becauſe the Water is already ſo ſaturated with this or other permanent Vapours or ſolid Subſtances, as not to be able to contain any other Vapour of the ſame or a different Kind in a State of Solution; but, when the Springs burſt through the Surface of the Ground the Preſſure of the incumbent Earth is removed, and theſe Maſſes of Vapour expanding themſelves exhibit Water with a Quantity of ſmall Particles of Vapour adhering to the Water or to Veſſels containing it, or to Subſtances immerſed therein. This Appearance happens, for the ſame Reaſon, upon withdrawing the Cork from a Bottle of vinous Liquor in a State of Fermentation, as Wine or Beer; which inſtantly foams and appears replete with minute Particles of permanent Vapour or *Gas Sylveſtre*; but when corked it was perfectly clear and without a Particle of Matter like Vapour in it.

Under

Under the flat Stones of the Pavement of the Bath are, probably, hollow Places that communicate with the Bath by Cracks between, or in the Seams of this Pavement. As the Bath fills, the Water occupies these hollow Places, and thus permanent Vapour being like other Substances in the Form of Vapour *adhesive*, Particles of it stick to the under Surface of the hollow Pavement, where they remain until they have collected in such Numbers as to attract each other and form larger and larger Masses. These becoming at length too large to be retained by the Power of Adhesion and incumbent Pressure of the Bath, contrarily to their specific Gravity and Elasticity, burst through the Seams of the Pavement, and pass in Clusters straight upwards to the Surface of the Bath: After a certain Time, this Vapour gathers as before, and the same Phenomenon is renewed.

The Manner of collecting permanent Vapour that arises spontaneously from BUXTON-WATER.

This permanent Vapour may be collected most conveniently by stepping into the Bath with a Bottle, of any Size you please, with a Funnel in it that has a wide Top. The Bottle with the Funnel in it are to be immersed in the Bath so as to fill them both with Water, and then inverted; taking Care to keep the Mouth of the Bottle immerged below the Surface of the Water.

 A Station

A Station muſt be taken in the Bath near which Bubbles in the greateſt Abundance have been obſerved to riſe, and by looking a little attentively on the Floor of the Bath, the Cluſters of Bubbles may be perceived to burſt from the Nicks or Holes of the Pavement: upon theſe being ſeen the inverted Funnel with the Bottle upon it is inſtantly to be held directly over them; by which Means they will be received within the Funnel and enter the inverted Bottle; where, a Bulk of Water will be expelled equal to the Bulk of permanent Vapour that has aſcended into the Bottle. The Bulk of a ſingle Cluſter of theſe Bubbles is various, being from one Drachm to two or ſometimes three Ounce Meaſures. By a little Practice a Quickneſs is acquired in perceiving the Bubbles as they burſt through the Pavement, and an Expertneſs in extending the Arm which holds the inverted Bottle and Funnel ſo as to catch them. In this Manner a Perſon may collect from about two to five Pint Meaſures of this permanent Vapour in an Hour, according to his Adroitneſs in the Management of the inverted Bottle and Funnel, and the Width of the Funnel; alſo according to the Difference in the Quantity of the Bubbles diſcharged from the Floor of the Bath in equal Times from the ſame Parts.

About thirty Quart Meaſures of the permanent Vapour that eſcapes ſpontaneouſly from Buxton-Water were collected in fourteen Days, by a Per-

ſon

ſon who ſtood an Hour at a Time in the Bath every Day, but who, commonly, held in each Hand a Bottle and inverted Funnel; by which Means near double the Quantity of this Subſtance was caught that is uſually collected in the ſame Time by only one Bottle and Funnel.

For certain Experiments, or when a ſmall Quantity of this permanent Vapour is only wanted, it may be collected very readily by merely holding a tumbler Drinking-Glaſs inverted in the Bath filled with Water over the Bubbles as they aſcend in the Bath, inſtead of the inverted Bottle and Funnel.

This permanent Vapour, (which is contained in the Water in minute Maſſes by the Preſſure and Coheſion of the Water in the Bath, and by the adheſive Property of this Vapour) may be procured by a Tube like a wide Barometer or Eudiometer-Tube, with a Funnel in it, filled with Water, and inverted in the Bath with the open End juſt below the Surface thereof: For by this Means the Particles of Vapour will be ſeen to extricate themſelves from the Water and gradually diſplace the Water in the Tube; eſpecially if this Tube and Funnel, or the Water of the Bath under it, be agitated.

It was uſual, in order to prevent this permanent Vapour from mixing with the Air of the Atmoſphere, to leave a little Water between the permanent Vapour and the Cork, and to preſerve the

the Bottle inverted; but, I believe, it will be ſufficient for this Purpoſe to cork the Bottles well with a ſound Cork and tie them over with a wet Bladder.

It has been ſhewn, p. 16 of this Vol. that theſe Bubbles are a compreſſible Subſtance. For Want of proper Inſtruments I could not determine the Spaces occupied under certain Degrees of Preſſure, but from ſome Experiments I ſhould be inclined to think that this Subſtance is ſubject to Laws, in this Reſpect, the ſame as thoſe of *Air*. The following Experiment will prove clearly the Property of *Compreſſibility*, in general, of this Subſtance.

Exper. V. A ſtrong Glaſs Tube one Inch and a half in Diameter, three Quarters of an Inch in Bore, and twenty Inches in Length was filled with Water. Ten Inches of Water within this Tube were then diſplaced by the Introduction of this *permanent Vapour*. A Cork previouſly found to be exactly the Width of the Bore of the Tube was forced within it while ſtanding inverted in Water, and the Water was obſerved to riſe juſt as high above the Mark denoting ten Inches of Vapour, as the Length of the Cork puſhed within the Tube. The Cork was then preſſed with a ſtrong Iron Rod, and the Preſſure, by this Means, reduced the permanent Vapour from a Column of ten to four Inches in Length; ſo that the Vapour was made more than twice as denſe as before.

The

The Heat of the Water in which the Tube ſtood, and of the Atmoſphere, were 40° of Fahrenheit's Thermometer.

To this Experiment I ſhall ſubjoin, that this permanent Vapour during Expoſure to an intenſe Degree of Cold, produced by a Mixture of concentrated nitrous Acid in a fluid Form and pounded Ice, preſerved its Form of Vapour and ſuffered no Alteration, but in its Dimenſions.

Although the Degree of Compreſſion to which this permanent Vapour was expoſed in this Experiment was by no Means the greateſt that might have been employed by proper Inſtruments, yet it was ſufficient to demonſtrate that the Compreſſibility of this Subſtance was not to be deſtroyed by conſiderable Preſſure. This Property of Compreſſibility together with its preſerving the Form of Vapour in intenſe Degrees of Cold authorize us to pronounce that this Subſtance belongs to the Claſs of permanent Vapours.

The Effects of great Degrees of Preſſure *long continued*, were not enquired into;—whether like *Air* it may be kept 16 or 20 Years in a highly condenſed State, as in a Wind-Gun, without loſing its Elaſticity.

Obſervations. Almoſt every Experiment with this permanent Vapour of Buxton-Water, ſhewed it to be readily altered in its *Bulk* by the Difference of the Degrees of *Heat* to which it was expoſed, as well as by Differences of *Preſſure*.

If

If Veſſels after being quite filled with this permanent Vapour as deſcribed, p. 23 of this Vol. were immediately corked, and after ſtanding ſome Time in a cool Place had their Corks withdrawn in cold Water or Quickſilver, the Fluid in which the Bottles were uncorked inſtantly ruſhed up into thoſe Veſſels containing this permanent Vapour; and upon Expoſure to Heat equal to that in which it was collected, namely, about 80°, the Fluid was expelled from theſe Bottles, and the permanent Vapour was of its former Volume.

If theſe Veſſels after being filled with this permanent Vapour were not corked but ſet to ſtand inverted in the Water or Quickſilver when the Atmoſphere was colder than the Bath Room; theſe Fluids roſe within the Bottles gradually, but *in the ſame Quantity only as when theſe Bottles had been corked immediately after collecting this permanant Vapour, and the Corks withdrawn in theſe Fluids, and when the Atmoſphere was of the ſame Temperature as that in which this gradual Diminution has taken Place in open Veſſels.* This permanent Vapour after this Contraction in its Bulk returned to its former Dimenſions on Expoſure to the Heat of the Bath-Room.

This Diminution of Bulk ſhewn by the riſing of Water or other Fluids under the above Circumſtances, I ſuſpect, has been miſtaken for *Abſorption*, and even conſidered as a Proof of a Part of a permanent

manent Vapour of this Kind in *Bath-Water* being Gas.

The Contraction ſuffered on expoſing this *permanent Vapour* immediately after collecting it, when it is heated to 75° or 80° of Fahrenheit's Thermometer, by ſtanding a few Hours in a temperate Heat or 50° to 60° of Fahrenheit's Thermometer and under a mean Preſſure of the Atmoſphere, was about one-fiftieth of its Bulk.

A ſecond ſtriking Inſtance, that occurred in the Courſe of my Enquiries, of the Expanſibility of this permanent Vapour was, that when the Hand was applied for any Purpoſe to a Florence Flaſk about three-fourths full of this Subſtance ſtanding inverted in Water *the Water viſibly deſcended in the Flaſk*, and upon withdrawing the Hand as *ſenſibly returned till it occupied the ſame Space within this Bottle as before.* If inſtead of a warm Hand, Snow was placed upon the Flaſk the Bulk of the included Vapour was diminiſhed, for the Water *viſibly roſe within it.*

On Account of this Property, it was difficult to cork a Flaſk quite full of this Vapour without expelling a Part of it, for as ſoon as the Hand was applied, before the Cork could be introduced, Bubbles were expelled through the Water in which the Flaſk ſtood inverted.

It was in Contemplation to make ſome Experiments with the View of learning *the Time in which this and other permanent Vapours received Heat,*

Heat, as ſhewn by their Expanſion, and *parted with Heat*, as ſhewn by contracting in their Dimenſions; but through want of proper Inſtruments this Deſign was only very incompletely executed by the following Experiment.

Exper. VI. I took two cylindrical Tubes as exactly as poſſible of the ſame Bore, which was three-fourths of an Inch; to each of theſe was applied a Tin Scale with Inches and Parts of Inches marked upon it, and made ſo as to ſlide upon them. Theſe Tubes being filled with, and inverted in Water, the permanent Vapour of Buxton-Water was introduced into *one*, and Air of the Atmoſphere into the *other*, in the Quantity of eight Inches of each according to the Index affixed, while ſtanding inverted the ſame Depth in a Veſſel of Water; the Heat of which was 40° and the Atmoſphere 42°.

The Tubes having ſtood a ſufficient Time, to aſſume the Temperature of the Water in which they were inverted, were removed into a Veſſel of Water heated to 120°; from which they were carried into *a Mixture of Snow, Salt and Water*; and then ſucceſſively placed in Water heated to 40°, 60°, 80°, 100°, 120°, 140°. The Alterations in the *Bulk* of the Vapours, and the *Times* in which the Alterations happened in theſe various Temperatures were noted, according as they were declared by the Index.

This

This Experiment was repeated ſeveral Times, and both the Tubes were alternately uſed for *each of the Vapours* on Account of there being ſome Difference of the Bore of them in particular Parts.

The Attentions particularly paid in this Experiment, beſides noting the Expanſions and Contractions, were to Meaſure the permanent Vapours from the Middle or moſt concave Point of the Surface of the Waters within the Tubes,—to preſerve the Tubes at equal Depths in the Water in which they were inverted,—to take Care that the Tubes were in exactly a perpendicular Poſition when the Reports were made from the Scale,—and to uſe Waters from which all the Air had been previouſly expelled by boiling.

The Reſult of this Experiment was, that there was very little Difference in the Contractions and Expanſions, and Time in which theſe happened, with equal Decrements and Increments of Heat; therefore according to this rather inaccurate Experiment, *the permanent Vapour of Buxton-Water is ſubject to the ſame Law with Regard to Expanſion as Air*.

The two following Experiments were intended to diſcover in a general Way the *ſpecific Gravity* of this permanent Vapour of Buxton-Water.

If this Subſtance be ſpecifically heavier than common Air, under equal Circumſtances of Heat, Preſſure, and Purity, it may be naturally expect-

ed,

ed, that it will form a Stratum immediately over the Bath; becauſe the Air of the Bath-Room is nearly of the ſame Temperature as that of this permanent Vapour of the Bath which is about 81°, provided it has no chymical Attraction for the Air of the Atmoſphere or by Motion it be not diffuſed therein; in the ſame Manner as a Stratum of Gas Sylveſtre (*m*) is frequently found over open Veſſels containing Liquors in a State of vinous Fermentation, and of Gas over certain Springs of the acidulous Kind (*n*) expoſed to the Atmoſphere.

Exper.

(*m*) It is well known that if a lighted Candle be held near the Surface of a Vat of fermenting Liquor it will be extinguiſhed, or if an Animal it will be ſuffocated. Inſtances frequently occur of People who unwarily expoſing themſelves to the Action of this Vapour, are by its sedative Power either killed immediately, or Apoplexy or Palſy are, ſeemingly, produced.

(*n*) *Seip* relates that Ducks ſwimming upon the acidulous Water near Spaw were killed by the Damp ariſing from it.

I have ſpeedily and with as little Motion as poſſible paſſed through Water in a ſmall Tub to the Surface more than a Gallon Meaſure of *Oil of Metals*, of this *permanent Vapour of Buxton-Water*, *of Air altered by Iron Filings and Sulphur*, by *Putrefaction*, and by *Reſpiration*; and, after Tranſmiſſion of each of theſe permanent Vapours through Water, held a lighted Wax Taper immediately over the Part whence they roſe through the Water, but it burnt as well as in common Air.

No Inference can juſtly be made concerning the ſpecific Gravity of that permanent Vapour which is called *Choke-Damp* by Engliſh Miners, nor of the *Vapour of the Grotta del*

Cane

Exper. VII. A *lighted Wax-Taper* was repeatedly placed just over various Parts of *the Gentleman's Bath at Buxton*, especially where the Bubbles rose and burst most frequently, and likewise

Cane and other Caverns, nor of the *Mofette* of the Italians, which proceeds from Apertures of the Earth especially previous and during the Irruption of Volcanos, and with which old Italian Lavas and many Springs upon Mount Ætna and Vesuvius abound, from their Effects upon Animals, Plants, and Flame near or at a Distance from the Parts of the Earth or Springs whence they arise; because these Vapours from their Confinement, Difference of Temperature from that of the Atmosphere, and great Abundance, as well as Substances with which they may be accidentally mixed, may manifest themselves as near unto, or at such Distances from their Sources as is not consistent with or would not be apprehended from their particular Gravities.

The whole Atmosphere of the little Island of Nesis was formerly infested with *Mofette*.

——————•—————— tali Spiramine Nesis
Emittit Stygium nebulosis Aëra Locis.

LUCAN. Lib. VI.

A permanent Vapour lighter considerably than the Air of the Atmosphere may produce its peculiar Effects just over the Part from which it arises; as for Instance, a lighted Candle placed near the Surface of a Spring from which that inflammable Vapour called *Fire-Damp*, a Substance perhaps 10 or 12 Times specifically lighter than common Air, separates itself, produces an Explosion or Flame upon the Surface of the Water, because it is detached so copiously that the Portion of Air immediately over the Spring contains such a Portion of this inflammable Vapour as to explode or burn before it has had Time to mix with the general Mass of the Atmosphere.

was expoſed at different Heights above the Surface of the Water, and even ſo as to be in Contact with the Bubbles of Vapour as they burſt in the Air; but it always burnt apparently as well, and as long as in the open Air.

This Experiment was made after the Doors of the Bath-Room had been ſhut cloſe a whole Night, and when the Water was in a tranquil State.

Exper. VIII. The Diminution taking Place on mixing two Meaſures, and alſo one Meaſure of *Air of various Parts of the above Bath-Room*, from near the Surface of the Water to the Top of the Room, with *nitrous Gas*, was the ſame or very little leſs than that with common Air mixt at the ſame Time with the ſame Quantity of the ſame Parcel of nitrous Gas.

The Air of the Bath-Room was examined by Mixture in this Experiment always after the Doors had been ſhut for ſome Time.

An Obſervation.

This permanent Vapour is very frequently eſcaping from the *Gentleman's Bath* at Buxton but not very abundantly in ſeveral Parts. The Bath occupies nearly the Whole of the Bottom of the Room, excepting the Seats for the Bathers, and the Room is of a moderate Height. There are two Doors in this Bath-Room which are commonly kept ſhut, but they have many ſmall Openings. Upon Enquiry it did not appear there was a ſingle

gle Inſtance of any Suffocation or Difficulty of Breathing having occurred on entering the Bath-Room or during bathing; and no Attention is paid to avoid coming near the Parts where the Cluſters of Bubbles riſe in the Bath.

Inference. From *Experiments* VII. and VIII. and the *Obſervation* juſt related, it is not probable that this *permanent Vapour* of Buxton-Water is much, or at all heavier than common *Air*; for it appears to diffuſe itſelf through the Air of the Bath-Room as ſoon as it eſcapes from the Water, and does not like Gas remain for ſome Time upon the Surface of Springs till it has gradually diffuſed itſelf throughout the Air of the Atmoſphere. It appears, moreover, that the Air of the Bath-Room is not liable to contain ſuch a Quantity of this permanent Vapour of Buxton-Water as to be ſenſible to the Teſt of nitrous Gas; a Difference indeed which I fully expected. It does not appear that this Air is even ſo impure, or more impure than the Air of a ſmall ſitting Room in which a Number of Perſons have been breathing, Candles burning, and Victuals ſtanding, after the Doors and Windows have been cloſed for ſome Time.

The ſmall Degree of Contamination ſuffered in the Air of this Bath-Room ariſes probably on Account of the *Diffuſibility* of *this permanent Vapour* of Buxton-Water through *common Air*, and its being as *light*, or *nearly as light*, or *lighter*

 than

than common Air; and, the great Quantity or ſtrong Current of external Air that is conſtantly entering the Room through the Apertures towards the Bottom of the Doors, and the Egreſs of heated and contaminated Air of the Bath-Room through the ſuperior Parts of the ſame Doors.

It is on Account of this Property that Bathers owe their Safety from the ſuffocating Effects of this permanent Vapour. The fixing of Ventilators would, however, obviate the noxious Effects of this Subſtance ſtill more effectually.

The next Experiments ſhew more clearly *the ſpecific Weight of this permanent Vapour.*

Exper. IX. I took three two Ounce wide Glaſs Veſſels, N° 1. contained *Oil of Metals* which was precipitated by adding diluted Acid of Vitriol to Iron-Filings; N° 2. was filled with the *permanent Vapour that ſpontaneouſly ariſes from Buxton-Water*; N° 3. contained *Gas* precipitated from Chalk by Acid.

Theſe Phials were inverted in Saucers of Water: after ſtanding an Hour they were turned upright ſucceſſively, taking Care to agitate them as little as poſſible, and a lighted Wax-Taper was applied to each of them *immediately*. The Event of applying this lighted Taper to the *Mouth* of N° 1. was an *Exploſion*; when the Flame was expoſed to the Mouth of N° 2. and N° 3. it was not extinguiſhed, but upon introducing it a little within the Necks of the Bottles it was put out.

Theſe Phials were filled, inverted, and left to ſtand as before: after being placed upright and ſtanding expoſed to the Air for the Space of *ten Seconds*, the lighted Wax-Taper was applied to the Mouth of each of them.

With N° 1. there was *no Exploſion*, but upon introducing the Taper within the Phial *a very weak Flame* extended itſelf for a Moment throughout the Phial. The Flame of the Taper was extinguiſhed in a Second or two after its Introduction into the Phial N° 2; and inſtantly put out upon being dipped into N° 3.

Theſe Phials were filled with the ſame permanent Vapours as before, and ſtood upright and expoſed to the Atmoſphere *for half a Minute* before the lighted Taper was applied to the Mouth of each of them.

The Phial N° 1. *neither exploded nor burnt* on introducing the lighted Taper within it. The Taper *burnt* as long in N° 2. as in common Air; and *was immediately extinguiſhed* in N° 3.

Upon another Occaſion, a half Pint Tumbler-Glaſs filled with *this permanent Vapour of Buxton-Water*; and another Glaſs of the ſame Figure and Size filled with *Gas*, with as little Motion as poſſible ſtood expoſed to the Air *two or three Minutes*; after which Time, on dipping the lighted Taper into the *firſt* Glaſs it was found to *burn* as in common Air, and in the *latter* it was *extinguiſhed*.

 As

As in this Experiment the *Oil of Metals* immediately mixed with the Atmoſphere, and had eſcaped before the permanent Vapours in the other two Phials, and as the *permanent Vapour that ſpontaneouſly riſes from Buxton-Water* had diffuſed itſelf through the Air of the Atmoſphere before the Gas, we may venture to pronounce in general, *that this permanent Vapour of Buxton-Water is not ſo heavy as Gas, nor ſo light as Oil of Metals: alſo that it readily diffuſes through common Air.*

The ſucceeding Experiment ſhews more deciſively this Inference to be juſt.

Exper. X. I filled two tall Jars, that contained about 12 Ounce Meaſures each, with *this permanent Vapour of Buxton-Water*; which ſtood ſome Time inverted in Saucers of Water along with *two ſimilar Jars of common Air.* Theſe Jars were exactly of the ſame Width. One of theſe Jars containing the *permanent Vapour of Buxton-Water* was placed *upright*, and another containing *common Air* was *inverted over it.*

The other Jar of *common Air* was ſet to ſtand *upright*, and the ſecond Jar of the *permanent Vapour of Buxton-Water* was inverted over the Mouth of the Jar of *common Air.*

Theſe *four* Jars ſtood expoſed to *as little Motion as poſſible*, in the ſame Temperature, for *ſix Minutes.* At this Time a lighted Wax-Taper was introduced within the Jar of *common Air* in-

verted over the Jar of *the permanent Vapour of Buxton-Water*, and it immediately *went out*, as well as on being inserted into the Jar of this permanent Vapour *on which it ſtood*. On introducing the Flame within the Jar of *common Air* on which ſtood *inverted* the Jar of *the permanent Vapour of Buxton-Water* it *burnt* as before, and was *extinguiſhed* on its Introduction into the Jar of permanent Vapour of Buxton-Water *inverted over this Jar of common Air*.

Two of the above Jars were filled with *Gas*: over *one* of them *was inverted* a Jar of *common Air*, and the other *was inverted over* a Jar of *common Air*.

After ſtanding *five Minutes* without Motion, the inverted Jar of *common Air* ſuffered a Candle to *burn* in it, but the Jar of *common Air over which was inverted* a Jar of *Gas* immediately *extinguiſhed Flame*. This Experiment was alſo performed with *Air altered by Reſpiration*, *by Iron-Filings and Sulphur*, and *by Putrefaction*. The Reſult was exactly the ſame as with *this permanent Vapour of Buxton-Water*.

Oil of Metals may be kept much longer in Bottles in an inverted Poſition than in Veſſels placed upright; and ſome pleaſing and ſurpriſing Phenomena may upon the Principle of the much leſs ſpecific Gravity of this Subſtance than common Air, be produced and explained.

 This

This Experiment not only proves, in general, *Oil of Metals to be much lighter, and Gas to be much heavier than the permanent Vapour that arises spontaneously from Buxton-Water, but renders it probable, that it is nearly as light, or rather lighter than common Air; and that its specific Gravity is about the same as that of Air altered by Respiration, Iron-Filings and Sulphur, and Putrefaction.*

The next Experiment was intended to determine more precisely the specific Gravity of the Subject under Investigation.

Exper. XI. A large Florence Flask containing about 40 Ounce Measures was filled with and inverted in a Tub of Water, where it stood inverted by passing the Neck of it through a Hole in a Shelf fixed in the Side of the Tub with the End of the Neck just below the Surface of the Water. The *permanent Vapours* intended to be *weighed* were transferred through the Water into the inverted Flask, in this Position; which, after remaining 12 *Hours* was corked while thus inverted with a soft and sound Cork, previously found to fit the Flask. The Flask thus filled with permanent Vapour was then removed from the Tub, and the Water adhering at the End of the Neck being wiped off with a dry Cloth, it was suspended, by Means of a String, to one End of a Balance that turned with one-sixteenth Part of a Grain, and its Weight ascertained. This done, the Flask was again inverted in the Water as be-

fore

fore and the Cork there withdrawn; and after remaining 12 *Hours longer* inverted was corked, dried, and weighed as before. The Flaſk was then inverted in the Tub of Water *a third Time*, the Cork withdrawn, and left to ſtand 12 *Hours*, after which it was corked, wiped dry, and weighed as before.

Erroneous Concluſions were attempted to be avoided by *repeatedly weighing* the ſame Species of permanent Vapour from the ſame, and different Parcels; by weighing them at different Times under *the ſame Preſſure*, and expoſed to *the ſame Temperature of the Air* and *Water* as nearly as poſſible. Attention was alſo paid to various other Circumſtances which might affect the Reſult of the Experiment, ſuch as to the Flaſk being perfectly *clean*; the Water *perfectly tranſparent*; to fill the Flaſk with *permanent Vapour quite full* when by ſome Variation in the Preſſure or Temperature of the Atmoſphere during ſtanding inverted, Water aſcended a little Way within the Neck of the Flaſk; to *avoid Loſs of permanent Vapour*, which was very liable to happen by the Heat of the Hand during the Time of corking the Flaſk, by interpoſing a cool Piece of Flannel between the Hand and the Flaſk; to uſe *the ſame String and Cork* in all the Trials; and to determine whether any Air had mixed with the *permanent Vapour* weighed, owing to the Inſufficiency of the Cork, by the Teſt of nitrous Gas; alſo *to*

weigh

weigh permanent Vapours of *a known Weight*, namely, common Air, Gas, and Oil of Metals, from which a Judgment might be made in general concerning the Truth of the Reſult of the Experiment.

The Flaſk of *permanent Vapour* was placed inverted *three Times* in order to drain off perfectly any Water that might be left, and by the Uniformity or Difference of Weight to be ſatisfied whether ſuch a Circumſtance had happened to affect the Reſult. There was no uniform Difference of either greater or leſs Weight happening from weighing Vapour *twenty-four*, and *thirty-ſix Hours after inverting the Flaſks*. The Difference of Weight between *twelve*, and *twenty-four Hours* was, for the moſt Part, half a Grain to a Grain and a half *leſs after the twenty-four, than after twelve Hours*; but ſometimes there was no Difference. Therefore it appeared that twenty-fours Hours was the whole Time neceſſary for the Flaſk to remain inverted in order to drain off completely any adhering Water.

As this Experiment was in its Nature a very delicate one, and the Method employed liable to more Errors than ſome other Ways of determining this Fact, I thought it prudent to repeat it, and put the Truth of the Reſult to the Teſt by the above Means. From ſo many Events it was hoped a tolerably well-founded Concluſion might be drawn.

As

As I wiſhed to determine whether the Properties of this permanent Vapour of Buxton-Water were the ſame as thoſe of *Air altered* by various Subſtances, ſeveral Parcels of Air changed in all or many of its Properties by different Proceſſes were alſo weighed.

This Experiment informed me,

1. That the Weight of *this permanent Vapour of Buxton-Water* is conſiderably different from that of *Gas* and *Oil of Metals, the former being five Grains, to five Grains and a half in a Pint heavier, and the latter ten Grains to ten Grains and a half in a Pint lighter than this permanent Vapour that ariſes ſpontaneouſly from Buxton tepid Springs, when the Barometer was* 29 *to* 29½ *Inches, and the Thermometer of Fahrenheit* 40° *to* 52°.

2. That this *permanent Vapour of Buxton-Water, was at leaſt as light as common Air*; and as all the ſeveral Parcels of *Air altered in its Properties by phlogiſtic Proceſſes* are probably of nearly the ſame ſpecific Gravity, or rather lighter than *atmoſpheric Air* (*o*), *this permanent Vapour of Buxton-Water is of the ſame, or nearly the ſame ſpecific Gravity as Air changed in its Qualities by various Proceſſes called phlogiſtic.*

3. *That this permanent Vapour of Buxton-Water is in all Probability rather lighter than common Air*;

(*o*) Exper. and Obſerv. on Air, by Dr. *Prieſtly*, Vol. II. p. 94.

but

but the Difference between this permanent Vapour and Air was not uniform, being from a *Quarter of a Grain to nearly half a Grain* in a Pint Meaſure lighter than atmoſpheric Air.

The ſame was the Reſult with Air *altered* by Iron-Filings and Brimſtone, with Air *changed* by Reſpiration and Putrefaction. Suppoſing this permanent Vapour of Buxton-Water to be a Compound of Phlogiſton and Air; as it has been found (*p*) that Air by a Candle burning therein is diminiſhed $\frac{1}{6}$ of its Bulk, and yet is rather lighter than the Air before it was combined with Phlogiſton, and Air is probaby diminiſhed $\frac{1}{3}$ or $\frac{1}{4}$ when fully ſaturated with Phlogiſton;—this Diminution of ſpecific Gravity of Air after Combination with Phlogiſton, can only be accounted for by conceiving, either that *ſomething is precipitated from Air*, during its Union with Phlogiſton, or that *by the Addition of Phlogiſton to Air it is rendered lighter*. Dr. Prieſtley found no Precipitation was made of Lime-Water when Air was combined with Phlogiſton by the Calcination of Metals: in Conſequence of which Union, the Air was diminiſhed $\frac{1}{4}$ of its Bulk, but I do not know that Air ſo combined with Phlogiſton has been weighed.

The Event of the foregoing Experiment being perfectly conſiſtent with, and agreeable to former

(*p*) A Treatiſe on Gaſes, p. 10.

Experi-

Experiments and Obſervations p. 32 to p. 40, of this Vol. we may place more Dependence upon the Reſult of each, than if the Concluſion had been founded on a ſingle Experiment or Obſervation.

The Fact ſhewn by this Experiment is a convincing Proof, that *this permanent Vapour of Buxton-Water is totally different from Gas.*

Concerning the Colour of the permanent Vapour that ariſes ſpontaneouſly from Buxton-Water.

It is not perhaps poſſible to diſcover the *Colour* of this permanent Vapour, on Account of the enormous Bulk requiſite to render this Property an Object of the Senſe of Viſion. We had not known the Colour of *Air* had it not been naturally preſented before us in that large Maſs which principally conſtitutes the Atmoſphere. When we look upwards we obſerve the Atmoſphere appears of *a blue Colour*, and of that Shade of Blue which is called from the Colour of the Air of the Atmoſphere Cerulean, or Sky-Blue. Alſo, Objects viſible at a very conſiderable Diſtance on Account of their Elevation in the Atmoſphere, as Hills, Foreſts, &c. are *blue*. *Euler* obſerves (*q*), and I have alſo had an Opportunity of obſerving, that the Foreſt of the Mountains of the Hartz, which are ſeen at Magdeburg, is *Blue*, but the ſame Object viewed at Halberſtadt is *Green*.

(*q*) See *Lettres à une Princeſs d'Allemagne*; and *D. Johann Peter Everhard*'s Erſtê Gründe der Naturlehre, p. 270.

Moſt

Moſt probably *this permanent Vapour* of Buxton-Water doth reflect coloured Rays, but the Colour is too dilute to be viſible in any Quantity we can obſerve at once; becauſe ſix, eight, or ten Quart Meaſures of it have been ſeen together in a Glaſs-Bell, but it did not appear that it had any Colour, or that Subſtances within this Receiver were different in their Appearance from that which they have in the Atmoſphere.

For the Appearance of this Subſtance mixt with or adhering to Water, ſee p. 152, 153. Vol. I.

To determine whether this permanent Vapour has any *Taſte* or *Smell* the two following Experiments were made.

Exper. XII. A ſmall Bladder filled with *this permanent Vapour* of Buxton-Water was fixed to the End of the Stem of a Tobacco-Pipe and by preſſing the Bladder a Stream of this Subſtance was forced upon the Tongue, but I could not perceive any Taſte.

Exper. XIII. A Bell-Glaſs containing four or five Quart Meaſures of *this permanent Vapour* of the tepid Springs of Buxton were made to paſs *ſuddenly*, and *ſpeedily* through Water into the open Air, and the Noſe was expoſed as long, and as nearly over the Part of the Water through which it aroſe as was thought prudent, but I was not able to diſcover *any Smell*.

Obſervations.

Obſervations.

The Property of being *ſonorous* may be inferred to belong to this permanent Vapour from its being *a Vapour*; becauſe Subſtances of this Claſs are capable of a vibratory Motion, that excites the Senſation of Sound. Moreover, I actually obſerved this Property to belong to this Subſtance; for when to a Receiver which was a Glaſs-Bell containing already ſeveral Quart Meaſures of this permanent Vapour a freſh Quantity was added ſo as to riſe *rapidly*, and in pretty conſiderable Quantity through Water into this Receiver, *a Noiſe was diſtinctly heard.*

This permanent Vapour is not only an Object of *Sight* and *Hearing* but of the *Feel*, for when it is forced through a Tube upon any Part of the Body externally it excites a Senſation exactly like *Wind.*

This permanent Vapour has the Quality of *Viſcidity* as well as, perhaps, all other permanent Vapours, by which we can account in ſome Meaſure for the Number of ſmall Bubbles of this Subſtance which are ſeen adhering to the Sides of Veſſels filled with Buxton-Water, or to Subſtances immerged in this Water.

Some Species of permanent Vapour are more viſcid than others.

The following Experiment manifeſts very clearly the Viſcidity of this permanent Vapour.

Exper.

Exper. XIII. Fill a Basin or Tub of a proper Size with Water that has had all its Air extricated by boiling, and has just cooled to about 40° or 50°. Invert a Phial filled with Water which has been boiled therein, and afterwards stood to cool, in the Basin or Tub of the same. Expel the Water from this Phial by pouring in this permanent Vapour. Then place the Phial upright, and wholly immerged in the Water; by which it will be again filled with this Fluid. Generally, *Bubbles will be seen sticking to the Sides of the Bottle* as soon as it is filled with Water, and pretty certainly if you expose this Phial thus filled with Water opposite a large Fire;—as the Phial grows warm many *Bubbles* will appear *adhering* to the Sides of the Phial.

I have now shown that the Bubbles spontaneously separated from Buxton-Water are *compressible*, and *elastic* in Degrees of Cold from that which is produced by a Mixture of nitrous Acid and powdered Ice, to Degrees of Heat far exceeding the greatest Heat of the Atmosphere and that they are therefore a *permanent Vapour*;—that this permanent Vapour is *not Gas* or *Air*;—that it is probably subject to the same Laws with regard to *Expansion by Heat* as well as with Regard to *Compression* as *Air*;—that it is *somewhat specifically lighter than Air*;—that it *diffuses readily through atmospheric Air*;—that it *does not refract visibly any coloured Rays*;—that it has *no Taste* or *Smell*;—that

it

it is *ſonorous*,—may be *felt*; and the Senſation excited by it is that of Wind,—and that it is a *viſcid Subſtance*.

I ſhall in the next Place relate;

Effects of the permanent Vapour that riſes ſpontaneouſly from Buxton-Water on ſeveral Claſſes of Animals.

Class I. *Quadrupeds.*

Exper. XIV. Mice, (*Mures domeſtici vulgares*) of various Ages and in various States of Vigour, were repeatedly conveyed through Water, heated to about 70°, into a Receiver containing three Ounce Meaſures of *this permanent Vapour* ſtanding inverted partially immerſed, upon a Stand, in a Baſin of this Water; inſtead of living about *twenty Minutes* without ſhewing Signs of Uneaſineſs, and about *ten Minutes* longer in a State of Uneaſineſs or Pain before dying, under theſe Circumſtances in *common Air*, they manifeſted Signs of Uneaſineſs, or they breathed ſhort and quick in a few Seconds of Time after they arrived in this Receiver to the Time of their Death; their Eyes then protruded, and they made two or three violent Exertions as if frantic and convulſed, ſhewn by leaping ſtreight up or againſt the Sides of the Glaſs—during theſe Exertions they tumbled down ſuddenly, and lay upon one Side, or flat upon their Bellies with all their Limbs ſpread out as if deprived of the Uſe of them,—gaſped a few

Times; and *died always in leſs than half a Minute after their Introduction into this Receiver.*

In ſome Experiments as the Water roſe higher within the inverted Glaſs after withdrawing the dead Mice, apparently, than before their Introduction, I was inclined to believe this permanent Vapour was diminiſhed in a ſmall Degree by Reſpiration; but upon a Repetition this Event did not happen in any ſenſible Degree.

A Mixture of two Meaſures of this permanent Vapour *after theſe Animals had died in it*, and one Meaſure of nitrous Air, produced in a greeniſh Phial a Shade of Orange-Colour, and meaſured, inſtead of three Meaſures or thereabouts as upon other Occaſions with this permanent Vapour before Mice had been ſtifled in it, only two Meaſures and $\frac{7}{9}$ or $\frac{8}{9}$.

The Explanation of this curious Fact ſuggeſted by Dr. Fordyce is, that the Animal in dying throws out a Portion of Air from its own Lungs, that it carried with it into the Receiver. I doubt however whether this Event always happens.

I imagined that this permanent Vapour might produce Colour, diminiſh with the above Compound of nitrous Acid and Phlogiſton, and be augmented in Bulk, in Proportion to the Number of Animals ſuffocated by a given Portion of it.

I found that a Mouſe would live full as long, perhaps rather longer, in a Receiver of this permanent Vapour in which eight or ten Mice had

been

been ſtifled; but the Bulk of it was not evidently increaſed, on the contrary was probably rather diminiſhed; and it diminiſhed with nitrous Gas as much only as after one Animal of this Species had expired in it.

A Mouſe was introduced within a Receiver containing two Ounce Meaſures of Gas Sylveſtre from fermenting Beer. It fell upon its Side in half a Minute, but lay in a convulſed State breathing for ten Minutes before it died. The Gas in which this Animal was ſuffocated diminiſhed with nitrous Gas, and the Mixture was a little turbid: ſo that it ſeems as if Air had been thrown out from the Lungs of the Mouſe included in this Gas, unleſs a Portion of common Air was accidentally mixed with it.

The permanent Vapour that ſpontaneouſly ſeparates itſelf from the tepid Spring mixt with a cold Spring (*r*), half a Mile South-weſt of the tepid Springs of Buxton, had the ſame Effect upon Animals as the permanent Vapour that extricates itſelf from Buxton-Water.

The Effects of this permanent Vapour of Buxton-Water upon Mice may be conſidered as an Example of the Effects of it upon Quadrupeds (*s*) in general; and, therefore, that it is incapa-

(*r*) See Vol. I. p. 147.

(*s*) Linné Syſtema Naturæ. T. I. Ed. 13. p. 19. I. MAMMALIA. *Fulcra:* Pedes quatuor, exceptis mere aquaticis.

ble of ſerving for the Reſpiration of Men, Monkies, Bats, Horſes, Aſſes, Cats, Dogs, Rats, Hogs, &c.

But it is a Queſtion upon what Principle this permanent Vapour is unfit for the Reſpiration of Quadrupeds.

It may induce Death, 1. by operating as a *Stimulus* upon their Lungs, in the ſame Manner, probably, that volatile vitriolic Acid ſuffocates Animals.

2. By its not having ſome Property that renders Air proper for Reſpiration, it becomes the efficient Cauſe of Death, in the ſame Manner as a Vacuum kills Animals.

3. By deſtroying immediately the *Irritability* of the animal Syſtem, as apparently happens when Death is occaſioned by Electricity.

In the above Experiment the Animals were not killed in ſo ſudden a Manner, as when Life is deſtroyed by the third efficient Cauſe; or, ſcarcely, ſo ſpeedily as when this Event is produced by the firſt Occaſion of Death, but the Phenomena cauſed by *this permanent Vapour* were ſuch as appear when Quadrupeds are included in exhauſted Receivers. Further, I am inclined to believe this Subſtance deſtroys Life by a negative Quality, becauſe in performing Experiments, when by Accident one Side of a Glaſs-Receiver filled with this permanent Vapour ſtanding inverted in Water, has been only for a Moment raiſed very

little above the Surface of the Water, in Conſequence of which there was only a Poſſibility of a very ſmall Quantity of *Air* getting into the Receiver, inſtead of a Mouſe dying therein in leſs than half a Minute, as would have happened before this Accident, this Animal would live ſeveral Minutes, or as long as might be expected in the ſmall Portion of Air introduced without Mixture with this permanent Vapour, or any other Subſtance incapable of ſerving for Reſpiration (*t*).

To

(*t*) When I was *altering* as much as poſſible a large Quantity of common Air by the Reſpiration of Quadrupeds for particular Experiments, as four Quart Meaſures of Air in a Glaſs-Bell employed as a Receiver, and made uſe of Mice for this Purpoſe; I found that after the firſt Mouſe introduced had died, which it did by growing gradually weaker, and expiring without Convulſions or frequently any Struggles, and not from the *Cold* of the Water in which the Receiver was inverted, the included Air that had been expoſed to the Effects of Reſpiration, diminiſhed on Mixture with nitrous Gas; and a freſh Mouſe being paſſed through Water into this Receiver, would live about half an Hour. After this ſecond Animal was introduced, the Air in the Receiver diminiſhed in Volume ſtill leſs with nitrous Gas than before. After this Time a third Animal of the ſame Kind as the former would live in this Receiver, although a ſhorter Time than the ſecond Mouſe lived, and the included Air, after the Death of this third Animal, was diminiſhed in Bulk ſtill leſs than before with nitrous Gas: Nor could I ever *alter* Air by Reſpiration ſo that it would not diminiſh at all with nitrous Gas. After a certain Number of Mice had been introduced

 into

To determine in ſome Meaſure this Queſtion the following Experiment was made.

Exper. XV. An Ounce and a half Meaſure of atmoſpheric Air was introduced into a Receiver containing one Quart Meaſure of this permanent Vapour of Buxton-Water;—a Mouſe was then paſſed through Water into this Mixture. The Conſequence was, this Animal lived nearly as long, and I am not certain if not with as little Pain or Uneaſineſs, as one might ſuppoſe it to live in an Ounce Meaſure

into the Receiver they always died in a few Seconds, and ſometimes inſtantly, convulſed; but then a Mixture of two Meaſures of the permanent Vapour thus altered by Reſpiration, and one equal Part of nitrous Gas, by Meaſurement after Mixture, was only two Parts and about $\frac{6}{9}$ or $\frac{7}{9}$. Hence it ſeems probable, that Air *altered* by Reſpiration kills Animals by a *negative Quality*, although they die without injuring a ſmall remaining Portion of Air; and when ſuch a Proportion of it remains, as if mixed with the ſame Proportion of permanent Vapour of Buxton-Water, would enable them to live a ſhort Time and *alter* it.

The Reaſon of ſeveral Animals being required to be ſucceſſively introduced to *alter* Air, to the Teſt of nitrous Gas and Reſpiration, as much as poſſible by breathing; and of an Animal living frequently for a ſhort Time in Air in which one or more Animals of the ſame Species had died by the *Alteration* produced by Reſpiration, has been explained by Mr. Keir (*ſee Notes, by Mr. Kirwan, to Scheele's Treatiſe on Air and Fire*) very ingeniouſly.—He found that only "the Air contiguous to an Animal is infected, and that a Candle will burn in a more diſtant Part of the ſame Air, and above the Animal." Mr. Kirwan ſays, "this ſhews that fixed Air only

ſure of common Air, that is about eight Minutes. To the Teſt of nitrous Gas, the Portion of Air added diminiſhed very little in Volume after the Extinction of the Life of this Animal. So that Reſpiration was performed by Means of the ſmall Portion of Air diffuſed through this Quantity of the permanent Vapour of Buxton-Water.

The above-related Event happened in the Courſe of my Experiments with Air *altered* by Reſpiration, Putrefaction, and the Mixture of Iron-Filings and Sulphur, to which ſmall Portions of

only is formed by Reſpiration, and not phlogiſticated Air; for this latter being ſpecifically lighter than common Air, ſhould be found over it." I do not know the Proofs in ſupport of this Aſſertion. Air altered by Reſpiration has never been ſhewn, as far as I know, to have the Properties of Gas; on the contrary, the known negative Properties ſhew that it is not Gas: Whether it be Air combined with Phlogiſton is not, perhaps, concluſively demonſtrated. The ſingle Proof given by Mr. Kirwan would equally prove Air *altered* by Inflammation to be Gas. The Difference of ſpecific Gravity, as I have found, between Air *altered* by Reſpiration and common Air is very inconſiderable. It is however probable, that the Gas ſeparated from the Lungs by breathing, or precipitated from common Air by Reſpiration, occupies the inferior Part of the Receiver on Account of its greater ſpecific Gravity than the other permanent Vapours, and that Air *altered* by Reſpiration is only gradually diffuſed throughout the whole Receiver; therefore the Air towards the Top of it may remain unaltered till the Air occupying the inferior Part is changed by Reſpiration. Does not the ſeemingly torpid State of Animals dying in confined Air in the ſame Manner as from Cold indicate the *ſedative Power of Air altered by Reſpiration?*

Air, as above-mentioned, were added: but having lately found that an Animal died as soon in a Mixture of the above Vapour of Buxton-Water and a small Portion of Air, nearly, as in the above permanent Vapour alone, I suspected I might have been mistaken in my former Experiments and Deductions, and therefore repeated the Trials: the Result of which was, that an Animal lived 15 Minutes, before it showed Signs of considerable Weakness, in ten Ounce Measures of the above permanent Vapour and one and a half Measure of common Air. On its Arrival in the Receiver, after being conveyed through Water heated to about 66°, it appeared to be in great Pain, and in a few Seconds began to gape and fell upon its Side apparently dead; it soon showed Signs of Life again, and was not seemingly in an uneasy State. After breathing in this Receiver 15 Minutes, as it appeared very languid and weak, an Ounce Measure of common Air was introduced, after which for the Space of two or three Minutes it did not appear to recover Strength, but afterwards recovered and lived 15 Minutes although it grew gradually weaker, without struggling or Convulsions. As it now seemed to be almost dead, it was withdrawn and placed near a warm Fire, where it lay several Minutes without shewing Signs of Life; but as it dried it recovered, and was well as before being subjected to this Experiment. I imagine sometimes Animals are choked as they are conveyed

veyed through Water, and on that Account die in the Receiver ſooner than they otherwiſe would do;—they ſhould alſo be made to ſit in the Receiver quite dry, out of the Reach of the Water; and the Water ſhould be kept warm.

In making this Experiment with Air *altered* by Reſpiration, Putrefaction, &c. the permanent Vapour ſhould be firſt transferred repeatedly through Water to ſeparate Gas, or other accidental Matters mixed therein; otherwiſe no Concluſion can be made concerning the Effects of the permanent Vapour that we wiſh to aſcertain.

The Iſſue of this Experiment renders it extremely probable that animal Life is not extinguiſhed by any *poſitive Property* of this permanent Vapour of Buxton-Water, at leaſt, not by a ſtimulant or ſedative Quality; becauſe it has no apparent or conſiderable Effect while expoſed to the Animal, in a very large Quantity, till the Portion of Air mixed with it be much altered.

The Freedom of Reſpiration in the Air of the Vault in which is the Bath at Buxton that ſeparates this permanent Vapour (*u*) is alſo a Proof of this Subſtance having *no ſtimulant*, or *ſedative Effects* to occaſion the Death of Quadrupeds included in Receivers of it. And upon this Principle may be explained the Obſervation of Mr. Boyle that Animals live *nearly* as long in Air in which Candles have burned out as in common Air.

(*u*) Page 152, 153, Vol. I. and 34, 35, of this Vol.

None

None of the permanent Vapours are capable to ſupport animal Life, or they are all ſuffocating excepting Air and dephlogiſticated Air (*x*) (if this laſt be deemed a diſtinct Species of Matter from pure Air); but they are not all Poiſons. For Inſtance, volatile vitriolic Acid is poiſonous but Gas is innoxious, and even medicinal. *Pliny* and the *antient Poets* mention various Springs that occaſioned the Death of thoſe Animals which drank of them (*y*), but from the Deſcription given by theſe Authors it is impoſſible to determine, whether they deſtroyed Life by acting as Poiſons when taken into the Stomach, or by a ſedative, ſtimulant, or negative Property operating upon the Lungs or nervous Syſtem in general. Many other Springs, of which Number are the *Acidulæ*, are mentioned by Writers of natural Hiſtory in antient Times as well as by modern Authors that oc-

(*x*) See Dr. Prieſtley's Experiments and Obſervations, Vol. II. p. 29.

(*y*) *Pliny* ſays the *Styx*, a Lake near Nonacris in Arcadia, has neither Smell nor Taſte, and occaſions Death as ſoon as it is drank.

Seneca's Deſcription of this Water is as follows. "Circa Nonacrin in Arcadia Styx appellata ab incolis advenas fallit, quia non facie non Odore ſuſpecta eſt: qualia ſunt magnorum Artificum venena quæ deprehendi, niſi morte, non poſſunt."

A Spring, which hiſſes like Water thrown upon Lime, is mentioned in France, that is fatal to Birds, by a late Writer whoſe Work I do not now recollect.

Pliny mentions Springs which are poiſonous when drank, and yet Fiſhes live in ſome of them.

caſion

casion noxious Effects, or at least disagreeable Consequences for a short Time, such as *Head-ach*, *Giddiness*, *Heaviness*, *Sleepiness*, *Delirium*, *Depravation* or *Loss of Sight* (z).

As the Intoxication occasioned by Wine is owing in Part to the *Gas Sylvestre* which it contains, and the *Gas Sylvestre* is either composed of Gas, that unites with Quicklime and forms calcareous Earth, and some other Substance; or is a Substance that has the essential Properties of Gas with some other peculiar Qualities superadded;—after the Discovery that the acidulous Quality of Springs was owing to Gas, it was inferred without Examination, that the efficient Cause of the above noxious or disagreeable Effects of *all Waters* was this permanent Vapour. As *Buxton-Water* was liable to produce some of these disagreeable Consequences, the Occasion of them was said to be Gas, but the very first Enquiry into this Matter shewed

(z) The River *Lyncestis* in Macedon is according to Pliny and Ovid, one of the *Acidulæ*, and produced the intoxicating Effects of Wine.

——————— Lyncestius amnis:
Quem quicunque parum moderato gutture traxit,
Haud aliter titubat, quam si mera Vina bibisset.
Ovid. Met. Lib. xv.

Cui non audita est obscenæ Salmacis unda
Æthiopesque Lacus? quos si quis Faucibus hausit
Aut furit aut mirum patitur gravitate soporem.
Ovid. Lib. xv.

Many Springs are called by the old Naturalists, from their intoxicating Effects, vinous Fountains.

the efficient Cauſe aſſigned not to exiſt, p. 19 of this Vol.; but it made appear another Species of permanent Vapour which we do not heſitate to pronounce is the only evident efficient Cauſe of the Vertigo, Head-ach, or Heavineſs ſubſequent to drinking Buxton-Water.

Having learned the Effects of this permanent Vapour on the *Lungs*, and *nervous Syſtem* in general of *Quadrupeds*; I made the following Experiment to afford an Inſtance or two, whether the permanent Vapour that ſeparates ſpontaneouſly from Buxton-Water be a medicinal, poiſonous, or inert Subſtance on the Syſtems of Quadrupeds, when applied to the *Stomach*.

Exper. XVI. An eight Ounce Phial containing five Ounce Meaſures of this *permanent Vapour*, and three Ounces of Water were placed inverted in a Baſin of Water oppoſite a large Fire; by which Means the permanent Vapour within the Phial was ſo rarefied as to expel all the Water contained within it; upon which, the Mouth of the Phial being ſtopt with the Finger, it was removed into a Baſin containing Solution of Gum Arabic of about the Conſiſtence of White of Egg. This Baſin with the inverted Phial being ſet in a cool Room the Solution ſoon filled, as the Water had done, three-eighths of the Bottle. It was then corked and the Vapour and Solution were mixt together, as much as poſſible, by Agitation;

—they

—they produced a *whitish Mixture full of small Bubbles.*

This Mixture was directed to be preserved inverted; and when used poured out as quickly as possible, and again corked as speedily as possible. It had no Taste or Smell. First one and then two Table-Spoonfuls were taken every four Hours.

In the Case of a Woman, aged sixty, labouring under a Catarrh, *Uneasiness at the Stomach, Sickness, Head-ach,* and *Purging* followed the taking of this Mixture into the Stomach: No obvious *Occasion* of these Effects appeared, excepting this Mixture.

This Mixture was given to a Patient in a Case under nearly similar Circumstances to the former, without any Consequences that could be referred to this Substance.

Both of these Cases of Disease were cured, but there was no Reason to suppose this *permanent Vapour* either impeded, or accelerated their Removal.

From the Experiment here related we infer, *that this permanent Vapour may be taken safely into the Stomach in much larger Doses than when swallowed by drinking Buxton-Water*; but what may be its particular Effects in the above Quantity or in a larger, or smaller Dose would require many Experiments to determine. If the Effects mentioned in the first Case of the Experiment were produced by this Substance they are Signs of its stimulant Power.

CLASS II. *Birds* (*a*).

Exper. XVII. A *Pullet* about eight Months old was immerſed in a Trough of River-Water heated to 60°, and its Head and Neck made to riſe within a wide Jar or Sugar-glaſs containing two Pint Meaſures of *the permanent Vapour that ariſes from Buxton-Water*. For about ten Seconds this Animal appeared to ſuffer no Pain, but afterwards it began to gape,—to ſtruggle a little,—to alternately cloſe and open its Eyes,—to ſhow Signs of Sickneſs by inclining its Neck and Head at Times,—and was motionleſs in about a Minute and a half from the Time of its Introduction into the Receiver and Immerſion in Water. Being then withdrawn it was found to be quite dead.

I ſuſpect this Bird would not have lived ſo long in this Experiment had there not been a ſmall Quantity of *Air* mixt with the above permanent Vapour, afforded by a Subſtance like Moſs growing in the Water in which this permanent Vapour of *Buxton-Water* had been kept.

CLASS III. *Fiſhes* (*b*).

Exper. XVIII. A weak *Eel*, in Weight about two Ounces, was introduced into a wide Jar con-

(*a*) *Quadrupeds* and *Birds* have double Hearts. two Auricles and two Ventricles—their Blood is warm and red—they have Lungs; and their breathing is involuntary.

(*b*) *Fiſhes* have ſingle Hearts—one Auricle and one Ventricle—their Blood is cold and red—moſt of them are furniſhed with Swimming-Bladders.

taining

taining a Pint and a half of this *permanent Vapour* of Buxton-Water; another Eel of about the same Size and in the same State was put into a similar Jar of *common Air*. The Jars stood inverted in River-Water, the Heat of which was 54°, and did not contain Water enough to cover the Fishes within them.

The Eel within the Jar of this *permanent Vapour* of Buxton-Water, moved itself about three Hours; after which Time, it was motionless. The Fish in the other Jar only shewed Signs of Life for two Hours.

A very lively Eel being cut asunder for a Purpose different from the Object of this Experiment, the Part with the Head of this Fish was introduced into a Jar containing about a Pint Measure of *this permanent Vapour* of Buxton-Water; and, the other Portion was put into another Jar, of the same Size, of *common Air*. Both Jars stood inverted in Water of a temperate Heat, and contained very little Water within them.

The Portion of this Eel in the Jar of this *permanent Vapour* of Buxton-Water wreathed itself, raised its Head, gaped much, and threw itself into various Postures, for more than half an Hour; and was not motionless, till *a Quarter of an Hour longer*. The other Portion ceased to move in about *ten Minutes*.

From this Experiment it appears, that this Species of Fish can live much longer than Quadrupeds

drupeds in this permanent Vapour of Buxton-Water.

The Eel living a ſhorter Time in common Air than in the other permanent Vapour, is moſt probably to be aſcribed to its being when introduced in ſuch a State as to be leſs able to ſupport Life than the other Individual of the ſame Species ſubjected to this Experiment.

I believe *Fiſhes* in general will live longer, and eſpecially Eels, which are remarkably tenacious of the Principle of Vitality, in exhauſted Receivers than *Quadrupeds*.

Exper. XIX. A very lively ſmall *Trout* was put under a large Water-Glaſs containing half a Pint Meaſure of this *permanent Vapour* of Buxton-Water, and three-fourths of a Pint of freſh River-Water heated to 50°. This Fiſh ſwam about without any Signs of Weakneſs or Uneaſineſs for *eight Minutes*, at which Time it began to *leap upon the Surface of the Water, then fell upon its Side, and lay without Motion*. It was immediately withdrawn and put into a Pail of freſh River-Water, where it lay a few Seconds *without Motion*: It then began to *move*, and in a few Minutes *quite recovered*.

This individual Fiſh was introduced a ſecond, and a third Time under the Glaſs with this *permanent Vapour* of Buxton-Water, and the ſame Appearances happened: And it was reſtored a third, and a fourth Time, as before, by being put

put into the Pail of River-Water. It did not ſeem have to ſuffered the leaſt Injury, by being thus repeatedly introduced and ſickened, by Confinement in the Receiver of Water and this *permanent Vapour*.

This ſame Fiſh was then put into the above Receiver with *common Air* inſtead of the above *permanent Vapour*, and under otherwiſe the aforementioned Circumſtance;—it *ſwam about*, *leaped frequently for five Minutes*, then began to *gape* and *throw out Bubbles* through the Water—fell upon its Side, and lay ſtill at the Bottom of the Water; but was recovered by throwing it into a Pail of freſh River-Water.

The ſame Event was produced by a ſecond, and a third Confinement of this individual Animal in this Receiver of freſh *common Air* and River-Water; and it was recovered a ſecond Time as before, but allowing it to remain more than a *Minute* the third Time upon its Side at the Bottom of the Water, it was found to be irrecoverable in the Pail of freſh River-Water.

The Iſſue of the preceding Experiment is very extraordinary, for it teaches us that the ſame Species of Fiſhes ſubjected to this Experiment lived longer confined in a Portion of this permanent Vapour of Buxton-Water and Water, than when confined in the ſame Portion of common Air and Water.

For if it ſhould be conceived, that a ſmall Part of a given Bulk of Air by being united with

 Phlogiſton,

Phlogiſton, renders the Air with which it is mixt, unfit to ſupport the Life of this Species of Animal, and therefore in about five Minutes the half Pint of Air in the inverted Water-Glaſs contained ſuch a Quantity of Phlogiſton or other Matters as to be no longer capable to aſſiſt the Life of this Creature; how doth it happen that this permanent Vapour, which is improper to ſerve for the Reſpiration of Quadrupeds, (p. 51, 52, this Vol.) and doth not combine with Phlogiſton, ſhould ſupport, at leaſt not deſtroy, its Vitality *in leſs than eight Minutes?*

The Truth of this Experiment is confirmed by the Event of the one immediately preceding, which ſhews, that Eels live longer in this permanent Vapour than in Air, or at leaſt as long as in Air.

Exper. XX. This Experiment was made to learn, whether the Buxton-Water was hurtful to, or deſtructive of the Life of Fiſhes; like Water impregnated with Gas, and Water containing nitrous Gas.

A very ſtrong and lively *Trout*, of about half a Pound in Weight, was let go into the Gentleman's Bath at Buxton. It immediately ſwam with great Velocity entirely round and near the Bottom of the Bath; then with Rapidity came to the Surface of the Water, and again plunged towards the Bottom of the Bath; immediately returned to the Surface; there moved

very

very weakly, turned upon its Back or Side, and ſhewing its white Belly fell, like a lifeleſs Animal, either ſick or dead to the Bottom of the Bath. It was taken out in a few Minutes, but could not be reſtored to Life by freſh River-Water, and cool Air.

This individual Animal was boiled along with two or three more of the ſame Species that had died merely for want of Water; but no Difference was perceived either in the Conſiſtence, or Taſte, between it and the others which had died out of Water in the open Air.

Pliny gives Inſtances of hot Water in which both *Fiſhes* and *Plants* lived. It is ſaid that no "living Creature" will live in the warm Bath at Aix.

Mr. John Hunter (*c*) found the Heat of a Pond 65° ½, and the Heat of the Stomach of a *Carp* therein 69°, or 3° ½ greater than the Water;—that a *Tench* bore the Heat of Water of 65°, and its own Heat was thereby increaſed from 41° to 55°;—that *Eels* live in 31° to 65°, and aſſume the Heat of the Medium in which they ſwim:—in ſhort that the actual Heat of Fiſhes may to certain Degrees be varied conſiſtently with Life according to the Temperature of the external Fluid, which is not the Caſe with Quadrupeds, at leaſt it is not the Caſe with one Species of this Claſs,

(*c*) Phil. Tranſ. Vol. LXVIII.

Man, whoſe Heat is very little varied by external Circumſtances. It is nearly the ſame when the Air is below 0, as when it is of the Heat of boiling Water or 212°, or even a much greater Heat—240° or 260°: a Degree of Heat in which Beef-Steaks and Eggs were roaſted in a few Minutes (*d*).

In Summer-Time it is common to find Fiſhes dead upon the Surface of Rivers or Pools, in Conſequence of the Water being heated to an unuſual Degree by the Sun-Beams acting upon the Banks of Rivers or Ponds. I was told by ſeveral credible Perſons, that a few Years ago on laying dry the Sough which carried off the Water from the Baths at Buxton to the River, ſome very large and lively Eels were taken in this Sough, where the Water was not many Degrees cooler than the Baths.

Having theſe Facts before me, I queſtioned whether the Death of the Trout, in the above Experiment, was occaſioned by the *Impregnation* of the Water; or, whether the Animal was not expoſed to greater *external Heat* than was conſiſtent with the vital Functions of its Syſtem; or, whether the *Air of the Bath-Room*, which this Fiſh ſought for ſo greedily while in the Bath, was not of a Temperature unfit for the Purpoſes of its Life.

(*d*) Phil. Tranſ. Vol. LXV. P. I. and P. II. for 1775.

Exper.

Exper. XXI. Several very lively ſmall *Trout* were put into the *Baſin of the Well*, p. 158, Vol. I. which is expoſed to the open Air on one Side of the Temple, within which it is incloſed.

In about *half a Minute* they appeared unable to bear the Water; they ſwam round the Baſin with great Celerity as if delirious or frightened, without any external Cauſe;—frequently leaped out of the Water for half a Minute longer; they then fell on their Side and tumbled motionleſs to the Bottom of the Well, from which they were immediately removed into freſh River-Water, where they recovered in a very ſhort Time.

Theſe Fiſhes were repeatedly ſubjected to this Experiment with the ſame Event, and as often recovered; excepting the laſt Time they were put into the Water of the Well, when being left longer than uſual at the Bottom of the Well in their State of Sickneſs before they were removed into River-Water, they could not be recovered.

It appears from this Experiment, that it was not the *warm Air* of the Bath-Room that deſtroyed Fiſhes in the Bath; but that Death was occaſioned either by the *Heat of the Water*, or its *Impregnation*.

Exper. XXII. As ſoon as a Tub containing the *tepid Water of Buxton* had cooled to 58° by ſtanding in the open Air, ſeveral ſmall Trout were put therein:—theſe Fiſhes lived without Signs of Weakneſs or Uneaſineſs for three Hours in this

Veſſel of cooled Buxton-Water, and were then removed.

Hence it does not ſeem probable, that Buxton-Water deſtroys the Life of Fiſhes in Conſequence of its *Impregnation*.

Exper. XXIII. The *Fiſhes* ſubjected to the laſt Experiment were let go into a Tub of *River-Water heated from* 80° *to* 82°, while the external Air was 50°. In about a Minute they all appeared upon the Surface of the Water, then ſwam about in great Agitation for about half a Minute; fell upon their Side, and tumbled to the Bottom of the Veſſel, apparently lifeleſs; but upon being inſtantly removed into cold River-Water they all ſoon recovered.

Theſe Fiſhes were ſeveral Times ſickened as above-mentioned, by Expoſure to this heated River-Water; and as often reſtored by Removal into cold River-Water.

From this Experiment it appears, that this Species of Fiſh, either for want of Cuſtom, or from the Nature of the Conſtitution cannot live in its native Medium, Water, of the Temperature of Buxton-Water, or of 82°: for, although the fluid Medium which they inhabit, Brooks or Rivers, varies in its Temperature very conſiderably, and they aſſume the Heat of the ſurrounding Fluid, yet all the Variety it is liable to is perhaps comprehended between 32° of fluid Water and 60°;—when theſe Limits are exceeded the

the Functions essential to Life can no longer be long performed.

But the natural Heat of the Fluids and Solids of *Men*, and many other Quadrupeds, not being like that of Trout and several other Fishes included between 32° and 60° according to the Temperature of the surrounding fluid Medium; but, uniformly preserving nearly the same Heat, to wit, about 97 Degrees, exposed to all the Varieties in the Heat of the external Medium of permanent Vapour in which they are destined to live; they are governed by different Laws concerning the Heat of their Constitutions from those of Fishes; and, therefore it is not surprizing that *Buxton-Water, or any common Spring-Water heated to* 82° *should be so great a Degree of Heat as to be intolerable to Fishes, and such a Degree of Heat as to excite the Sensation of Coolness* (*e*), *when the Bodies of living Men, and perhaps many other Animals of the same Class* (*f*), *are immersed therein. But when Water exceeds* 104° *or* 106° *it is also in-*

(*e*) Water heated to 82° as I have found by repeated Trials, excites the Sensation of *Coolness* rather than of *Warmth* or *Cold*—a Fact of practical Importance.

(*f*) I was told at Buxton, that the Heat of Buxton-Water, or of the Heat of the Air of the Bath-Room is in a short Time fatal to Water-Rats, as appeared by turning an Animal of this Kind into the Bath; but I wish this Experiment to be repeated before this Fact be credited.

tolerable to the Conſtitutions of Men on Account of its Heat (*g*).

CLASS IV. *Amphibious Animals* (*h*).

Exper. XXIV. A very lively ſmall *Newyt*, a Species of the Lizard, was put into a Receiver containing three Ounce Meaſures of the permamanent Vapour of Buxton-Water juſt collected from the Bath, and a ſmall Quantity of Water, but not nearly ſufficient to cover the Animal. This Veſſel was ſet to ſtand in cold Water. The included Newyt *crawled* upon the Sides of the Receiver, and *gaped* frequently for ſome Time; but at laſt it *adhered* to the Side of the Glaſs, where it continued without the leaſt Motion for an Hour and a half. This Animal was then withdrawn and thrown, apparently dead, into a Baſin, containing a little cold Water. In a few Minutes it diſcharged Bubbles from its Mouth, after which it ſuddenly ran round the Baſin and appeared as lively as ever.

This Animal after being perfectly recovered, was introduced a ſecond Time into the Receiver

(*g*) Conſult the Experiments of my Friend Dr. *Parr* of *Exeter*, publiſhed in his Inaugural Diſſertation at Edinburgh, 1773; of which there is an Analyſis in the firſt Volume of the Medical Commentaries of Edinburgh.

(*h*) This Claſs of Animals have, like Fiſhes, only ſingle Hearts,—one Auricle and one Ventricle—their Blood is red and cold—they have Lungs, and their Reſpiration is voluntary.

of

of this permanent Vapour; in which it walked about and gaped much for about five Minutes. It was then motionleſs, and not being diſturbed remained in that State for three Hours. This Newyt, as was ſuppoſed being quite dead, was removed into a Baſin with a little cold Water. In about an Hour it ſhewed Signs of Life, but appeared extremely weak and unable to move; being left all Night, it was the next Morning found to have ſo far recovered as to have crept up the Sides of a deep Baſin and made its Eſcape.

The permanent Vapour, in which this amphibious Creature had lived ſo long, mixed with an equal Bulk of nitrous Air, diminiſhed from 20 to 18 Parts.

Exper. XXV. A lively *Frog* was conveyed through Water into a Jar containing about ten Ounce Meaſures of this permanent Vapour of Buxton-Water that ſeparates ſpontaneouſly; there was about half an Ounce of Water alſo within this Jar. This Animal appeared uneaſy in a few Minutes; after which Time it gaped frequently, and ſhewed Signs of Pain:—in about two Hours and a half it was motionleſs, and apparently dead. In this State it was ſuffered to remain more than an Hour longer: it was then withdrawn with every Appearance of a dead flaccid Animal. It was put into a Cup with a little Water, and left in a Room of the Temperature of about 55° for

three Hours. It then appeared in the ſame Poſition as I firſt left it in, and ſuppoſing it dead I took it up in my Hand to throw it aſide, but to my Surprize, upon being touched it leaped up as if awoke from ſleep, and did not appear to have ſuffered from the Experiment.

This Animal was immediately introduced into the ſame Jar as before, and was obſerved to again ſhew Signs of Uneaſineſs for an Hour. It was left all Night in this Jar and the next Morning appeared dead: it was then removed into a Baſin with a little Water, and expoſed to the open Air of the Temperature of 55°, but it was not by this Means reſtored to Life as before.

Dr. Prieſtley found that a Frog ſtruggled two or three Minutes confined in nitrous Gas, and could not be reſtored after being expoſed a Quarter of an Hour to this permanent Vapour. Probably this Gas kills Animals by ſome poſitive Property like volatile vitriolic Acid, but the above permanent Vapour deſtroys Life by a negative Property.

This Experiment furniſhes another Proof of the Probability that thoſe Animals which live long in exhauſted Receivers, as Snails, Frogs, Snakes, and other Amphibia (*i*), alſo require a long

(*i*) The Reaſon of this Claſs of Animals living longer without Air than Quadrupeds is aſſigned from a Conſideration of the Structure of the Parts appearing on Diſſection, by *Baglivi*—*Opera omnia*, p. 442.

long Time before they die in Receivers of this permanent Vapour of Buxton-Water, as well as, according to my Obſervation, in *Air combined with Phlogiſton*; and, that they die therein, for the ſame Reaſon that they cannot live in Vacuo.

Or we may account for the torpid State of Animals of this Claſs by Expoſure to the above permanent Vapour, on the ſame Principle that the Sleep of the *Hamſter* or German Marmot is accounted for in the Monthly Review for Nov. 1782, p. 366. " At the Approach of Winter they (the *Hamſters*) ſhut up the Apertures of their Holes with great Addreſs. There, if undiſturbed by the human Race, they feed on their Stores in perfect Tranquillity till the Severity of the Froſt, or rather perhaps, as will appear afterwards, the Air *phlogiſticated* by them, in Conjunction with the Cold, brings them to a torpid State. If, at this Time, the Holes are opened the Hamſter is found lying upon a Bed of ſoft Straw; the Eyes are ſhut, and when the Eye-lids are forced open, they inſtantly cloſe again. The Members are ſtiff, like thoſe of a dead Animal; and the whole Body feels as cold as Ice. When diſſected, however, even at this Period, the Heart is ſeen alter-

Boerhaave, in his Chymiſtry, obſerves, that Animals whoſe Hearts have two Ventricles, and no Foramen Ovale, as Cats, Dogs, Mice, Birds, &c. die in half a Minute in the Receiver of the Air-Pump, counting from the firſt Exſuction, and a *Mole* as ſoon; but that a *Bat* lived longer.

nately

nately contracting and dilating; but at the ſlow Rate of fifteen Pulſations in a Minute. This Animal's Heart, in its active State, beats 150 Strokes in the ſame Time. The Inteſtines diſcover not the ſmalleſt Degree of Irritability, even on the Application of Spirit of Wine or Oil of Vitriol. Neverthelefs, the Animal ſometimes opens his Mouth, as if he wanted to reſpire.

" Mr. de Buffon is not anſwerable for our preceding Obſervation with Reſpect to the *Phlogiſtication* of the Air; but we find that the Hamſter which he had in his keeping in *the open Air* did not become torpid though expoſed to a Degree of Cold during the Winter, probably ſuperior to that which the Hamſters endure in a State of Nature, at the Depth of three, four, or five Feet under the Surface of the Ground. Beſides, according to M. Allamand's curious Account of this Animal, a Hamſter ſhut up in a Cage filled with Earth and Straw, and expoſed to the open Air in a Window, to a Degree of Cold ſufficient to freeze Water never becomes torpid. But if the Cage be ſunk four or five Feet under-ground, and be well ſecured againſt the *Acceſs of Air*, he becomes, at the End of eight or ten Days, as torpid as if he had been ſuffered to remain in his own Burrow. If the Cage be now brought up to the Surface, even in the coldeſt Weather, the Hamſter will awake in a few Hours: and on putting him below the Earth his torpid State will

after

after a proper Interval, return. Warmth, nevertheless, undoubtedly accelerates, and Cold retards, his Revivifcence. His temporary Death and Refurrection probably depends upon thefe two conjointly."

CLASS V. *Infects* (*k*).

Exper. XXVI. *Flies* of various Species, namely, Bees, Wafps, and Butterflies, were put into Phials of the permanent Vapour that efcapes fpontaneoufly from Buxton-Water; but as many of thefe Animals could not be fafely paffed through Water, fometimes a fmall Quantity of Air muft almoft neceffarily be fuppofed to have mixed with this Vapour, before the Bottles were corked.

Thefe Animals lived feveral Hours in this Vapour, without being apparently affected; and would no Doubt have lived ftill longer had they not been fet at Liberty. A ftrong lively Moth was feemingly killed in a few Seconds in an Ounce Phial of this permanent Vapour of Buxton-Water in which Putrefaction had taken place, and lay for dead in the open Air for an Hour;—it then came to Life again.

This *Moth* was introduced a fecond Time along with a common black Fly. The Moth lived 15 Minutes, and was then motionlefs: the Fly appeared lively and well four Hours longer.

(*k*) *Infects* have fingle Hearts—one Auricle and one Ventricle,—their Blood is white and cold,—they have no Lungs, but lateral breathing Holes, called *Spiracula*.

I put

I put a ſmall Quantity of Water containing putrefied animal and vegetable Matter, and which I obſerved by Means of a good Magnifier to abound with *Animalcules* not unlike *Millepedes*, into a Phial containing about four Ounce Meaſures of the permanent Vapour of Buxton-Water that riſes ſpontaneouſly; which was corked and inverted. Another Portion of this fetid Water was poured into a four Ounce Phial filled with common Air, corked and inverted. And a third Phial containing this foul Water was left open. Theſe *three* Bottles were placed in the ſame Expoſure and after 12 and 24 Hours Animalcules were obſerved as before, although *diminiſhed in Number*, and apparently *changed in Kind* in each of the Bottles. After two Days no living Animals could be diſcovered in any of the Phials.

I ſuppoſe the *Animalcules* in the Phial of permanent Vapour of Buxton-Water found ſufficient Air for the natural Term of their Life in the Water from, perhaps, Plants growing in the Water; and that the permanent Vapour of Buxton-Water poſſeſſes no poſitive noxious Quality.

Mr. *Scheele* found *Flies* lived ſeveral Days and did not *diminiſh* the Bulk of Air in which they were confined; but that after they were dead the *Milk of Lime* diminiſhed its Bulk one-fourth Part, and the reſt extinguiſhed a Candle.

Bees, *Caterpillars* and *Butterflies*, after living in confined Air and dying therein, while the inverted

ed Veſſel in which they were included ſtood in Lime-Water, were found to diminiſh its Bulk very conſiderably; and form or to precipitate a conſiderable Quantity of *Gas*: for the Water roſe daily within the Receiver. This great Diminution of Bulk Mr. *Kirwan*, with good Reaſon, aſcribes to the Motion of this Animal, occaſioning them to phlogiſticate more completely the Air in which they were confined than moſt other Animals.

Mr. *Kirwan* ſeems to have expected that *Bees*, &c. ſhould have lived as well in confined Air as in the open Air; becauſe Dr. Prieſtley found that *Inſects* live in *putrid Air*. And he explains their Death in Mr. *Scheele*'s Experiment by obſerving, that they probably died for Want of Nouriſhment: but I confeſs it appears to me that they died clearly becauſe the confined Air was rendered unfit for further ſupporting the Functions of theſe Animals; and if other *Inſects* lived longer in Air *altered* by Putrefaction, I apprehend it was not confined Air but communicated with the ambient Air, or was mixed with common Air.

Inſects in general have been found to live a long Time in Vacuo, viz. Waſps, Bees, Hornets, Graſshoppers, Lady Cows, the Animalcules in Pepper-Water, &c. and it has been lately obſerved that this Claſs of Animals live in Air infected by Putrefaction. Dr. Prieſtley found Waſps, Butterflies, Spiders and Flies either died immediately or in a very ſhort Time in nitrous

Gas,

Gas, Exp. and Obſ. Vol. I. p. 227, but by Expoſure to inflammable Air, Waſps were rendered torpid, and recovered on being removed into the open Air.

This Experiment ſhews, that this permanent Vapour of Buxton-Water and perhaps Air combined with Phlogiſton, or *altered* by Reſpiration, Putrefaction, and phlogiſtic Proceſſes, deſtroys the Principle of Life for the ſame Reaſon that a Vacuum does.

The other Claſſes of Animals were not included in Receivers of this permanent Vapour, but I am inclined to think the Effects would have been found to be the ſame as thoſe of a Vacuum.

It was next enquired, whether this permanent Vapour of Buxton-Water will, like Air, combine with that Subſtance called Phlogiſton, and thereby decompoſe thoſe Things of which this Subſtance may be a component or elementary Part.

Exper. XXVII. A ſmall Piece, about four Grains in Weight, of *Phoſphorus*, was conveyed into a two Ounce Phial filled with *this permanent Vapour of Buxton-Water*. This Phial ſtood inverted in a Baſin containing Quickſilver, and the Phoſphorus was paſſed through this Fluid into this permanent Vapour.

This permanent Vapour was previouſly found not to diminiſh on Mixture with nitrous Gas.

The ſame Quantity of Phoſphorus was introduced, in the above Manner, and under the above Circumſtances, into a Phial of *common Air*.

Both

Both these Phials were equally *luminous* in the Dark, and continued to shine several Hours:—when they were exposed near a Fire they were still more luminous, and filled with *white Steam*.

This Experiment was several Times repeated with different Parcels of this permanent Vapour of Buxton-Water, and with the same Result.

The Appearance in this Experiment was rather surprising; because, the *Light* produced by Phosphorus is believed to be occasioned by the Phlogiston of this Substance combining with Air only, or by the Inflammation of the Phosphorus. But it is here shewn that Phosphorus produces Light included in a permanent Vapour totally different from Air, and therefore that the shining of Phosphorus is not a Criterion of Air (*l*).

Phosphorus

(*l*) *Phosphorus* is decomposed slowly by *Air*, perhaps in all the various Temperatures of the Atmosphere near the Surface of the Earth, and produces, during this Decomposition, or *Inflammation*, *Light*, but no sensible *Heat*, or but a small Degree of Heat. It is also decomposed, by greater *Heat* than that of the Atmosphere, *rapidly*; during which *Inflammation*, or more properly *Combustion*, there is much Light and Flame, and very great Heat.

Sulphur, Iron, &c. decompose or burn in the Heat of the Atmosphere, as well as when exposed to greater Degrees of Heat.

The Light emitted from animal and vegetable Matters undergoing the mucilaginous and putrefactive Fermentations, is probably occasioned by the Air of the Atmosphere decomposing *Phosphorus*; for, by these Fermentations, to the Test of

Phoſphorus has been found upon ſome Occaſions to emit Light in exhauſted Receivers, but the Experiments were not made with ſuch Attention as to enable us to determine whether this luminous Appearance might not be produced by a ſmall Quantity of Air in an extremely rarified State left in the Receiver after it was exhauſted.

Dr.

Silver, and Paper impregnated with Solution of Saccharum Saturni, Phlogiſton is detached; and phoſphoric Acid, either combined or in a ſeparate State, is alſo formed or extricated. By the Union of this phoſphoric Acid and Phlogiſton, Phoſphorus is formed within the mucilaginous or putrid Maſs; which Compound, upon Expoſure to the Atmoſphere during the two above-mentioned fermentative Proceſſes, is decompoſed by the Air of the Atmoſphere attracting the Phlogiſton of the Phoſphorus ſtronger than it is attracted by the Acid of Phoſphorus.

The *Light* produced from animal Matter while in a State of Preſervation from Fermentation by Means of Sea-Salt, or Nitre, has the ſame efficient Cauſe as the *Light* of the above Subſtances; becauſe the Fermentations of the animal Subſtance are only partially prevented taking Place.

The Light or Flame emitted from the Bodies of certain living Animals *, may be accounted for on the Suppoſition, that ſuch Animals excrete or ſecrete Phoſphorus; which is decompoſed immediately upon its Expoſure to the Air on the Surface of their Bodies; and, the Acid of Phoſphorus remaining after this elective Attraction has taken Place is either combined with the atmoſpheric Air alſo, or is taken up by the Abſorbents.

* ——— "Menam's orient Stream that nightly ſhines
With Inſect Lamps"———————

The

Dr. *Prieſtley* found Phoſphorus to ſhine and ſmoke in *marine acid Air*, juſt as it would have done in *common Air*, but not in *alkaline, nitrous* or *vitriolic acid Air*. Dr. *Rutherford* ſays, Phoſphorus of Urine continues to burn and ſhine in Air in which a Candle has burnt out (*m*).

The luminous Appearance of the Sea, ſo frequently obſerved, is probably occaſioned either by the Decompoſition of Phoſphorus formed by the Fermentation of animal or vegetable Matters, extricated from theſe Subſtances, and mixed with the Water; which Particles of Phoſphorus being expoſed to the Air by the Motion of the Sea, as happens eſpecially in a Gale, are decompoſed, and therefore emit Light; or by living Animals ſeparating Phoſphorus, and producing Flame in the ſame Manner as they do upon other Occaſions.

The *Aurora Borealis* may, perhaps, be explained upon the Principle of Phoſphorus decompoſed by the Air of the Atmoſphere; but it may ſeem difficult to ſtate the Circumſtances for ſuch an Operation in the Atmoſphere, becauſe it is found, that Phoſphorus burns in all the known Temperatures of the Atmoſphere: Therefore cannot long exiſt there without being decompounded. This Difficulty may probably be removed by ſuppoſing, Acid of Phoſphorus, which is ſaid to be frequently diffuſed through many Parts of the Atmoſphere, to unite with Phlogiſton in Regions where the Cold is too great for the Air to decompoſe Phoſphorus, and therefore under ſuch a Circumſtance this Compound may be found in Air without being decompoſed. But when by Motions in the Atmoſphere this Subſtance is conveyed into more inferior, and conſequently leſs cold Regions of the circumambient Air, it will then be decompoſed; the Effect of which is that Meteor called northern Lights or Streamers.

(*m*) Diſſertatio Inauguralis, 1772, p. 19.

In the Courſe of ſome Experiments I had occaſion *to powder Phoſphorus*, in the Manner deſcribed by Dr. Fordyce, (Phil. Tranſ. Vol. LXVI. p. 11.). An eight Ounce Phial, half full of Water, containing ſome *Phoſphorus of Urine* was held near a Fire until it was heated ſo as to melt the Phoſphorus; in which State it was agitated and reduced to Powder. Before, as well as after, Agitation, the empty Part of the Phial was filled with white Fumes or Smoke, and in the Dark it was very luminous; but *upon ſtanding* corked the *Light vaniſhed*, and was *renewed in a moſt vivid Degree*, throughout the whole Phial, *by Agitation*; and upon the leaſt Motion of the Water, it was a juſt Reſemblance of the phoſphoreal Light of the Sea. This Phenomenon excited my Curioſity to know, *whether it would happen in any Kind of permanent Vapour, as well as Air.*

Exper. XXVIII. An eight Ounce Phial, containing about eight or ten Grains of *Phoſphorus of Urine*, was filled with diſtilled Water recently boiled, into which were transferred about three Ounce Meaſures of *Air*, to the Teſt of nitrous Gas, *wholly changed* by Expoſure to a Mixture of Iron-Filings and Sulphur. The Phial was corked and preſerved inverted, and immediately upon the Introduction of this *altered Air* the Part occupied by it was uniformly *whitiſh* as from Smoke, and in the Dark was *luminous*. Moreover the whole Phial *ſhone while agitated*, and was *luminous*

in

in the Part filled with this permanent Vapour soon after being shook, but *upon standing, the Light disappeared*, and was again restored *upon the least Motion*, so as to render the Surface of the Wave of Water thereby produced visible.

After agitating this Phial some Time, in a warm Room, without any other View than amusing myself with the Phenomenon of the Light produced, it was carried to a Tub of Water in order to mix the permanent Vapour it contained with nitrous Gas; when to my Surprize some Bubbles which escaped through the Water into the open Air, although the Room was lighted with Candles, were seen to emit Light, or burn with a Flame distinctly upon the Surface of the Water; and I produced this pleasing Appearance several Times with this Parcel of permanent Vapour.

This Experiment was repeated with fresh *Air altered* by a Mixture of Iron and Sulphur, with the same Event; excepting that it did not burn upon its Appearance on the Surface of the Water as on the first Trial.

The Experiment was also repeated with Air *completely changed*, according to the Test of nitrous Gas, by Respiration, and by Putrefaction; with Oil of Metals, Gas, nitrous Gas, common Air, and various Mixtures of these permanent Vapours with each other; in all of which the Phenomena above-related happened, if not without, certainly on Exposure of the confined permanent Vapours

to Heat, excepting the ſpontaneous Inflammation with Light, that manifeſted itſelf upon paſſing the permanent Vapour through Water, upon the Surface of that Fluid, and expoſed to the Atmoſphere in the firſt Trial of this Experiment. By Attention, however, and Repetitions of this Experiment, I diſcovered the Circumſtances neceſſary to the Production of the *Flame* obſerved the firſt Time of performing this Experiment on paſſing the permanent Vapour through Water.

I found that the Phial with any of the above permanent Vapours as above-deſcribed, emits Light if not without, certainly with *Agitation*, and *Expoſure to Warmth*; during which, the Part of the Phial occupied by the permanent Vapour had its Tranſparency diſturbed by a whitiſh Fume. If the Phial be agitated frequently for ſome Time, and during that Time be kept very warm, by being placed near a large Fire, the permanent Vapour will in general become again *tranſparent*, and as ſoon as its *Tranſparency* was reſtored, and not before, it was found to have *loſt its Property of affording Light*, although aſſiſted by Heat and Agitation; even Heat to the Degree of rendering the Phoſphorus *fluid* in the included permanent Vapour.

In this tranſparent State the permanent Vapour, eſpecially if warmed, being paſſed through Water, on its Arrival upon the Surface thereof expoſed to the Air, exhibited a beautiful Flame,

for

for the Space of a few Seconds. This Effect may perhaps always be produced with most of the permanent Vapours, that are capable of being rendered transparent by long Agitation; but *Gas could not be rendered transparent*, therefore, afforded *no flaming Vapour*; and *nitrous Gas, although it was rendered transparent, never blazed upon the Water.*

If permanent Vapour, by the above Means, rendered capable of *flaming* spontaneously on mere Exposure to the Atmosphere was poured into a Tube, instead of being passed through Water into the Air, *no Light* was produced; but as soon as common Air was added to it in the Tube, in two or three Trials, it was for a few Moments *quite light* in the Part of the Tube occupied by the permanent Vapours.

The *Light* in the Phial containing Phosphorus, Water, and permanent Vapour, appeared to be transmitted from the Phosphorus at the Bottom of the Vessel through the Water, and not from Particles of this Substance adhering to the Sides of the Phial, in the Part containing the permanent Vapour, or floating upon the Surface of the Water; for it was produced when no Particles adhered to the Sides of the Vessel, and when Water was added to fill the Phial brimful, *no Light* was produced upon the Surface of the Water above the Neck of this Bottle; and, because when this Water was poured off, in the Dark, into a Basin,

there was no luminous Appearance upon the Surface of the Fluid thrown out.

This Experiment accounts for the phoſphoreal Light at Sea extending itſelf throughout the Subſtance of the Water to ſome Depth, and not being merely ſuperficial.

After the Light vaniſhed by continuing the Agitation and the included permanent Vapour had become *tranſparent*, on adding a freſh Quantity of permanent Vapour to the Phial containing the ſame Phoſphorus and permanent Vapour in which *Light* could no longer be produced, the luminous Appearance was renewed. To the Teſt of *nitrous Gas*, none of the above-mentioned permanent Vapours after Agitation in Water with Phoſphorus were altered, excepting the *common Air*. The Inflammability of the *Oil of Metals* was not by this Means diminiſhed, or increaſed; and all the other permanent Vapours extinguiſhed Flame, excepting that upon one or two Occaſions they exploded a little on Contact with a lighted Taper; which Effect was moſt probably occaſioned by ſome Particles of Phoſphorus that chanced to be ſuſpended in the permanent Vapour. Nitrous Gas ſaturated the ſame Quantity of common Air with Phlogiſton, as before it was ſubjected to this Experiment.

As it appeared that *Light* was produced for a conſiderable Time, without Agitation, by Warmth, from a very ſmall Quantity of Phoſphorus in Water;

ter; and, as according to the foregoing Experiment there is Reaſon to believe by *Motion* it would produce Light for many Days, perhaps for ſeveral Weeks, it occurred that if Phoſphorus were put into a very large white Glaſs Bottle blown thin or a very large Receiver containing a ſmall Quantity of Water, and were preſerved inverted, or the Veſſels were cloſely ſhut ſo as to exclude effectually the external Air, *Light* might be produced in ſufficient Quantity for ſome Purpoſes in Mining; when on Account of the Abundance of *Fire-Damp* in certain ſubterraneous Countries this Buſineſs cannot be carried on by the Aſſiſtance of burning Subſtances which furniſh Light. Upon ſuch Occaſions the Light produced by ſtriking a Pick-axe againſt a hard Stone, and the Light afforded by Heads of Fiſhes in a naſcent putreſcent State is all the Light the Miners have to aſſiſt them in their Labour. If ſuch Means be ſufficient, Phoſphorus as above deſcribed included in a Receiver with Water and permanent Vapour might anſwer much better.

The ſpontaneous Inflammation of permanent Vapour on Expoſure to the Atmoſphere reminded me of a ſimilar Phenomenon of Nature which had been communicated to me by a Gentleman of Accuracy and Judgment, namely, that in India there are Springs which ſpontaneouſly exhibit a Flame upon the Surface of the Water as ſoon as they burſt out of the Earth; but which,

I believe,

I believe, only appears upon the Water in the Part where they ooze out of the Ground.

Suppofing a Vapour of this Sort to be formed in the Earth by Putrefaction or other Proceffes, and to break out through certain Fiffures or Pores of the Ground, it would produce a Phenomenon juftly refembling the *Ignis fatuus*.

The Explanation of the Appearances in this Experiment, that I have been able to conceive, is this. When Phofphorus is expofed to the Action of Air it is deprived of its Phlogifton until it forms a Compound—Air faturated with Phlogifton. If this *Compound of Air and Phlogifton*, or any of the above-mentioned permanent Vapours excepting Air, be applied fo as to act upon Phofphorus, a chymical Combination alfo takes Place, fhewn by the turbid State of the permanent Vapour, and fubfequent Tranfparency; either between Phofphorus or the Phlogifton of the Phofphorus and permanent Vapour, till (*n*) the permanent Vapour be faturated; by which Union a Compound is formed readily decompofed on the

(*n*) Inflammable Subftances upon other Occafions have been found to decompofe in, or have their Phlogifton attracted by, various permanent Vapours as well as Air; for Dr. Prieftley found, that the Phlogifton which is feparated from a Mixture of Iron-Filings and Sulphur in Air is alfo, probably, extricated from this Mixture included in Receivers of *nitrous* Gas, Air faturated by nitrous Gas, *Gas, Oil of Metals*, and in exhaufted Receivers, or excluded by Water from permanent Vapours of any Sort. See Exper. and Obf. Vol. I, II, III.

Appli-

Application of Air; becauſe Air attracts more ſtrongly the Phoſphorus or the Phlogiſton of the Phoſphorus united with Air ſaturated with Phlogiſton of the Phoſphorus, and the other permanent Vapours ſubjected to this Experiment, than this Compound of Air and Phlogiſton and theſe other permanent Vapours attract Phoſphorus, and the Phlogiſton of Phoſphorus.

The next Subſtance examined with the View mentioned p. 80. l. 14. of this Vol. was *nitrous Gas.*

Nitrous Gas is a permanent Vapour compoſed of nitrous Acid and a large Proportion of the Principle of Inflammability (*o*): it is decompoſed by Air, becauſe

(*o*) " A Metal in its metallic Form is a Compound of a pure Calx and a Subſtance which has been called inflammable Air, but which is an Oil found out by Stahl to exiſt in Metals, and which we would call the Oil of Metals. The nitrous Acid decompoſes this Oil at the ſame Time that it acts on the Calx itſelf."—Dr. Fordyce, Ph. Tr. Hence we underſtand why no Oil of Metals is precipitated by the Solution of Metals in nitrous Acid, and how nitrous Gas is formed.

In order to learn whether Oil of Metals would be decompoſed by nitrous Acid, and by nitrous Acid combined with Phlogiſton, or by nitrous Gas, I made the following Experiment.

A Phial, containing one Ounce of Water and ſix Ounce Meaſures of Oil of Metals, was expoſed to Heat, and inverted in a Saucer of Water, ſo as to empty the Bottle of the Water it contained; upon which it was removed with the Mouth ſtopt with the Finger into a Baſin of concentrated nitrous Acid, in which about as much nitrous Acid roſe within the Phial as Water had been expelled. It was then cloſed with a Glaſs Stopper, and ſtood inverted in a warm Expoſure ſeveral Weeks; during which it was frequently agitated. Along with

because Phlogiston has a stronger Attraction for Air than for nitrous Acid; and during the Decomposition of this Substance by Air, Heat is sensibly produced, but without Light or Flame (*p*), attended with a turbid Appearance, yellowish Fumes, or Smoke: a Diminution in the Sum of the Bulk of the two Substances mixt together, and Transparency are immediately subsequent to these Appearances.

It is to Dr. Priestley that Philosophy is indebted for the Discovery of this permanent Vapour,

with this Phial stood a Mixture composed of equal Quantities, viz. an Ounce Measure each, of Oil of Metals, and nitrous Gas, in a Phial inverted containing a very small Portion of Water.

After standing the Time above-mentioned, on Examination, the Mixture of *Oil of Metals* and *nitrous Gas* was inflammable as before, and did not diminish with nitrous Gas; the *Oil of Metals* which had stood exposed to the Action of the nitrous Acid was also as inflammable as before, and did not diminish with nitrous Gas;—therefore *Oil of Metals could not be decomposed by nitrous Acid, or nitrous Gas*; but they perhaps may effect a Decomposition under different Circumstances.

(*p*) In order to discover whether any Light was produced by the Decomposition of nitrous Gas the following Experiment was made.

To a Flask, inverted in Water, containing a Pint and a half of common Air and a Pint of Water, was added in the Dark as speedily as possible, a Pint Measure of nitrous Gas; and the Mixture was agitated:—the Flask felt warm, but no Light was perceived. In a few Minutes the Mixture was transparent, and the Dimensions of it were much less than the Sum of the Bulk of the two Substances composing it before they were added together.

which

which he called nitrous Air, (Exper. and Obſer. Vol. I. Sect. 6.) agreeable to his Phraſeology, viz. the denominating permanent Vapours of all Species, Airs.

This Philoſopher alſo ſhewed (*q*), that no permanent Vapour decompoſes this permanent Vapour but *Ai.* ; and, that therefore this Subſtance might be moſt uſefully applied to diſcover not only the Preſence of Air, but the Purity of Air, or the Proportion it bears in Mixtures of this permanent Vapour and other permanent Vapours, Fluids, and Solids.

Nitrous Gas is then, an inflammable Subſtance, becauſe the *Phlogiſton,* which is an eſſential or elementary Part of its Conſtitution, is attracted by Air; and thereby is effected the Decompoſition of nitrous Gas, the Production of Heat, and a Compound formed conſiſting of Phlogiſton and Air.

Nitrous Gas belongs alſo, probably, to that Kind of inflammable Subſtance, called Oil; becauſe *it burns*, and *is not ſoluble in Water* (*r*);

(*q*) Exper. and Obſ. p. 114. " It is exceedingly remarkable that this Effervescence and Diminution, occaſioned by the Mixture of nitrons Air, is peculiar to common Air, or Air fit for Reſpiration; and as far as I can judge from a great Number of Obſervations, is at leaſt very nearly, if not exactly, in Proportion to its Fitneſs for this Purpoſe; ſo that, by this Means, the Goodneſs of Air may be diſtinguiſhed much more accurately than it can be done, by putting Mice, or any other Animals to breathe in it."

(*r*) Dr. Fordyce's Elements of Agriculture, p. 44.

and as *Oil of Metals* is decompofed in Confequence of the Phlogifton which enters into its Compofition being attracted by Air, and is a Subftance *infoluble in Water*, it is alfo on the fame Grounds pronounced to be Oil (*s*). Hitherto however Mankind have not been accuftomed to conceive Oil in the Form of permanent Vapour, but Subftances only which are Fluids or Solids in the various Temperatures of the Atmofphere; as the Fat of Animals, Ether, Phofphorus, Oil expreffed from the Seeds and Fruits of certain Vegetables, &c.

It has been already demonftrated that on adding the permanent Vapour of Buxton-Water to nitrous Gas, there was no Heat or Difturbance in the Tranfparency of thefe permanent Vapours mixt together; and no fubfequent Tranfparency, and Diminution in the Sum of the Dimenfions of the Subftances compofing the Mixture, p. 17, this Vol. Therefore there are no Signs of the Inflammation of nitrous Gas in the permanent Vapour of Buxton-Water that rifes fpontaneoufly, but as the Quantity of the Subftances mixed together might not be fufficient to make the Signs of burning obfervable, I made the following Experiment.

Exper. XXIX. To a Pint Meafure of nitrous Gas contained in a Florentine Flafk, inverted in Water, the Neck with Part of the Shoulder of which was broke off, was added a Pint and a

(*s*) See Notes (*o*), p. 91, and (*r*), p. 93, this Vol.

half

half Meaſure of this *permanent Vapour* of Buxton-Water as ſpeedily as poſſible: not the leaſt *Heat*, or *Diſturbance of Tranſparency* were perceived; nor any ſubſequent *Diminution* in the Sum of the Bulk of the two Subſtances after Mixture diſcovered, excepting what might be allowed for the Inaccuracy of the Method uſed for meaſuring the Bulk of permanent Vapours.

This Experiment determined that nitrous Gas doth not burn in, or is not decompoſed by, this permanent Vapour of Buxton-Water, at leaſt not in a Manner that can be made ſenſible by this Experiment; but the permanent Vapour ſeparated by Means of Heat, (p. 231. Exper. XVIII and XIX. Vol. I.) has been ſhewn to be *Air mixed with ſome other Subſtance.*

Therefore as it is now proved that the permanent Vapour which detaches itſelf ſpontaneouſly from Buxton-Water, (p. 152, 153. Vol. I.) and is alſo obſerved mixed in the Form of ſmall Bubbles with this Water, (p. 152. Vol. I.) is a permanent Vapour totally different from Air, it is ſhewn that there is the greateſt Probability that the Subſtance mixed with the Air procured by expoſing this Water to a boiling Heat, (p. 239. Vol. I.) is this permanent Vapour that ſeparates itſelf ſpontaneouſly and is mixed in Form of ſmall Bubbles with Buxton-Water.

To demonſtrate further whether the permanent Vapour procured from Buxton-Water by boiling

be Air mixed with the permanent Vapour that riſes ſpontaneouſly, and the *Proportion* of theſe to each other, the following Experiment was contrived.

Exper. XXX. I mixed the permanent Vapour which riſes ſpontaneouſly from Buxton-Water with Air, in the following Proportions.

N° I. A Mixture of *equal Quantities* of the permanent Vapour that riſes ſpontaneouſly from Buxton-Water and common Air.

Two Meaſures of this Mixture and one Meaſure of nitrous Gas mixed together, produced a ſomewhat turbid Appearance, no ſenſible Heat, and meaſured after Mixture two Meaſures and one-fourth. On Repetition of this Trial the ſame Appearances enſued, and the Mixture meaſured two Meaſures and eleven thirty-ſixth's of a Meaſure: and on a third Trial three Meaſures of theſe two Subſtances meaſured two Meaſures and $\frac{1}{3}$.

Equal Quantities of this Mixture and nitrous Gas, after ſtanding together, were reduced between one Meaſure and five-ninth's, and one Meaſure and twenty-three-thirty-ſixth's, as appeared on ſix Trials.

One Meaſure of this permanent Vapour of Buxton-Water, and half a Meaſure of nitrous Gas, meaſured after Mixture, Agitation, and ſtanding, the ſame as the Sum of the two Subſtances ſeparately, or one and a half Meaſure; excepting about $\frac{1}{36}$ of a Meaſure exceeding, or leſs than, this Bulk. But after adding half a Meaſure of Air to this Mix-

Mixture it meaſured one Meaſure and $\frac{11}{18}$ of a Meaſure.

N° 2. A Mixture of *two* Meaſures of this permanent Vapour of Buxton-Water, and *one* Meaſure of Air.

Two Meaſures of this Mixture and one Meaſure of nitrous Gas, mixed together, meaſured in the Trials made, two Meaſures and $\frac{5}{9}$; two Meaſures and $\frac{4}{9}$; two Meaſures and $\frac{13}{36}$ of a Meaſure.

Equal Bulks of this Mixture and nitrous Gas, after being agitated together, meaſured from one Meaſure and $\frac{67}{80}$ to one Meaſure and $\frac{63}{80}$.

N° 3. A Mixture of *three* Parts of this permanent Vapour of Buxton-Water and *one* equal Part of common Air.

Two Meaſures of this Mixture and one Meaſure of nitrous Gas meaſured on the Trials made two Meaſures and $\frac{5}{9}$, and two Meaſures and $\frac{7}{18}$ of a Meaſure.

N° 4. A Mixture of *one* Part of this permanent Vapour of Buxton-Water and *three* Parts of common Air.

Two Meaſures of this Mixture and one Meaſure of nitrous Gas meaſured, after ſtanding together, two Meaſures and $\frac{1}{18}$. Two Trials.

N° 5. A Mixture of *two* Parts of common Air and *one* Part of this permanent Vapour of Buxton-Water.

Two Meaſures of this Mixture and one Meaſure of nitrous Gas meaſured, after Mixture and

ſtanding together, two and $\frac{1}{18}$ to two Meaſures and $\frac{1}{6}$. Four Trials.

Equal Parts of this Mixture and nitrous Gas meaſured one Meaſure and $\frac{6}{10}$ to one Meaſure and $\frac{27}{40}$ of a Meaſure, as appeared on ſeven Trials.

Two Meaſures of Air in which a Candle had burnt out and one Meaſure of nitrous Gas meaſured two Meaſures and $\frac{1}{9}$: and at the ſame Time two Meaſures of common Air and one Meaſure of nitrous Gas meaſured nearly two Meaſures.

Eſtimating the Proportion of common Air to the other permanent Vapour that is ſeparated along with it by Heat from Buxton-Water, by the Teſt of nitrous Gas applied to Mixtures of theſe two Subſtances in various Proportions, the *ſmalleſt* Proportion of Air is *one* Part of this Vapour to *three* Parts, or rather more, of the permanent Vapour of Buxton-Water; and the *greateſt* Proportion is *three* Parts of Air and *one* Part of the permanent Vapour that riſes ſpontaneouſly—p. 236, Vol. I.

There is no Difficulty in accounting for the Difference of the Proportion of theſe two Subſtances.

1. As the permanent Vapour that riſes ſpontaneouſly from Buxton-Water is contained therein in a State of *Suſpenſion*, by being divided into ſmall Maſſes as Oil in Water, as well as, probably, *Solution*, and the Circumſtances which occaſion this Suſpenſion are liable to vary exceedingly, the

Quantity

Quantity of a given Bulk of this Subſtance in Water, recently taken from the Bath, muſt alſo vary; and, therefore ſuppoſing the Quantity of Air contained in a given Quantity of Water to be always the ſame, becauſe it is either *combined* with, or *diffuſed* through, this Water, we can readily underſtand how it happens that different Parcels of Water ſeparate theſe two permanent Vapours in different Proportions to each other when expoſed to Heat.

2. The Proportion of theſe two permanent Vapours to each other is not only liable to be different in different Parcels of Water, but if the permanent Vapour ſeparated by Heat from the ſame Parcel of Water be received in different Veſſels, each Veſſel will be liable to contain theſe two Subſtances in various Proportions:—from the different States* of *Mixture* and *Combination* in which they are contained in the Water, they will probably be extricated at different Times, or in unequal Proportions at the ſame Times.

Suppoſe we conſider the Quantity of permanent Vapour contained in Buxton-Water ſeparable by Heat to be four Ounce Meaſures, in a moderate Heat of the Air, in ſixteen Pints of Water, according to a former Experiment, p. 233, Vol. I. then the mean Proportion of Air and the other permanent Vapour to each other is about equal Quantities of the permanent Vapour that riſes ſpontaneouſly, and of Air; or about two Ounce

 Meaſures

Measures of the permanent Vapour that extricates itself from Buxton-Water, and the same Bulk of Air, in this Quantity of Water; so that a Pint of Buxton-Water contains one Drachm Measure of the former permanent Vapour, and about as much Air: and Buxton-Water contains $\frac{1}{64}$ of its Bulk of permanent Vapour of the above two Kinds and Proportions separable by Heat (*t*).

The

(*t*) This may be the proper Place to observe, that Dr. Higgins in his Advertisement, mentioned p. 310, Vol. I., after stating the Quantity of Sediment, and the Kind of Substances of which this Sediment consisted, in a Winchester Gallon of Buxton-Water, says, this Quantity of Buxton-Water contained "four Ounce Measures of *phlogisticated Air*, and two Ounce Measures of *acidulous Gas*, exclusive of the Quantity retained by the calcareous Earth in the Heat of boiling Water." These two Vapours Dr. Higgins reports were found in his Examination of a Gallon of Buxton-Water, filled April 1, 1782, under the Inspection of Mr. Benjamin Priolu, Bath-Man; therefore it is evident, the permanent Vapour that arises spontaneously from Buxton-Water, p. 152, 153, Vol. I., did not *in a separate State* fall under the Notice of this excellent Chymist; but probably those Vapours which are separable from it by Means of Heat, p. 231 to 240, Vol. I. The Vapours I found by this Means were a Mixture of *Air* and *the permanent Vapour that arises spontaneously from Buxton-Water*, p. 236, Vol. I. and p. 75, Vol. II. The Result of Dr. Higgins's Experiments is in this Part of the Analysis of Buxton-Water different from mine. He says he obtained "four Ounce Measures of phlogisticated Air, and two Ounce Measures of acidulous Gas

from

The Effects of the above Mixtures on *Animals*, related in the following Experiment, ſhew further the Reſemblance between them and the permanent Vapour obtained from Buxton-Water ſubjected

from a Wincheſter Gallon of Buxton-Water." By what Method Dr. Higgins ſeparated theſe Vapours is not mentioned. Nor does he define what is to be underſtood by the Term phlogiſticated Air. If by this Term he means permanent Vapour which *extinguiſhes Flame* and which is *not Gas*, without other Properties being conſidered, this Subſtance, called phlogiſticated Air, may be the permanent Vapour I found p. 237, Vol. I. I could not ſeparate any Gas, by Means of Heat, from this Water, p. 235, 244, Vol. I.; and by elective Attraction, p. 263, Vol. I. only one Ounce Meaſure of this Gas from ſeven Ounce Meaſures of Buxton-Water. Unleſs Dr. Higgins had publiſhed the Experiments from which he gave the above Reſult, it is impoſſible for the Public to determine whether his Account, or mine, of the permanent Vapour of Buxton-Water be beſt eſtabliſhed by Proofs. In the mean Time the Reader will pleaſe to conſider attentively the Methods I have purſued, and the Obſervations I have made in various Parts of this Work, particularly p. 231 to 303, Vol. I.; and judge for himſelf concerning the Sufficiency of the Experiments to make appear the Subſtances and Properties for which they were intended, and alſo with Regard to the Juſtice of my Deductions and Remarks.

As in the above-quoted Analyſis of Buxton-Water *phlogiſticated Air* is mentioned to have been found therein, I think it neceſſary to obſerve, to juſtify the Aſſertion I have made in a former Part of this Work, that till the Experiments related p. 16 to 20, of this Vol. the permanent Vapour that ariſes ſpontaneouſly from Buxton-Water was

subjected to a boiling Heat, p. 237, 238, 239. Vol. I.

Exper. XXXI. Into a Receiver containing two Ounce Measures of the Mixture N° 2. of last

Exper.

universally believed to be Gas, that I could not derive any Assistance from that Account because the Date of its Publication in a Hand-Bill is June 9, 1782, and the Water of which the Examination was made in is this Advertisement said to be "filled the 1st of April (1782) under the Inspection of Mr. Benjamin Priolu, Bath-Man;" whereas I made the Experiments, which shewed this permanent Vapour to be a totally different Species of Matter from Gas, about the 2d or 3d of February of the same Year, in the Presence of Mr. *Buxton*, (p. 19, this Vol.); and in the Course of that Month communicated the Result of them to several of my Friends; among others, to Dr. *Fordyce* in London, and Dr. *Duncan* in Edinburgh.

Also in the Month of April 1782, I had the Honour and Satisfaction of examining along with the Hon. Mr. H. Cavendish, the Nature of the permanent Vapour that rises spontaneously from Buxton-Water, and the permanent Vapour separated by boiling from this Water, by Mixture with nitrous Gas. These Trials being made with the most accurate and best contrived Instruments hitherto known, I shall, for the further Satisfaction of the Reader relate the Result of them.

First one, and then a second Measure of nitrous Gas was added to two Measures of the permanent Vapour examined, as nearly as could be made: Accordingly, the first Column contains the Quantity of permanent Vapour according to Measure; the second Column the Bulk of this Vapour after Mixture with, as accurately as possible, one Measure of nitrous Gas. The third Column shews the Bulk of the two

Measures

Exper. was introduced a *Mouſe.* This Animal lived without apparent Uneaſineſs *four* Minutes; —it then had a Shortneſs of breathing and ſtaring with Protruſion of its Eyes; and in *four* Minutes more it expired.

Into the ſame Receiver containing two Ounce Meaſures of the Mixture of N° 1. of laſt Exper. a Mouſe was conveyed. It lived ſeemingly with-

Meaſures of permanent Vapour mixed with one Meaſure of nitrous Gas to which a ſecond Meaſure of nitrous Gas was added. Hence may be ſeen the Difficulty, or Impoſſibility of obtaining, preciſely, by Meaſure a required Quantity of Vapour, and the ſame Quantity ſeveral Times together.

		With one Meaſure of nitrous Gas.	With a ſecond Meaſure of nitrous Gas.
N° 1. Two Meaſures of the permanent Vapour that riſes ſpontaneouſly from Buxton-Water were found to meaſure in the Eudiometer Tube — —	2,02	2,89	
Ditto from a different Parcel	2,025	2,85	
N° 2. Air phlogiſticated by Iron-Filings and Sulphur — —	2,000	2,88	
N° 3. Permanent Vapour from Buxton-Water by Means of a boiling Heat of Water — —	2,028	1,82	2,315
N° 4. Air in which a Candle had burnt out — — —	1,995	1,78	2,49
Trials by Weight, in which only one Meaſure of the above Vapours were uſed.		Obſervable Diminution.	True Diminution.
N° 1. — — — —	,998	,138	,138
N° 2. — — — —	1,008	,085	,085
N° 3. — — — —	,998	,928	,930
N° 4. — — — —	,992	,799	1,806
Common Air — — —			1,08

out Pain for *six* Minutes then shewed Signs of Uneasiness, and died with its Eyes appearing as if ready to start out of its Head.

These Animals diminished the Volume of these Mixtures in which they were included. It appears that these Mixtures had the same Effects on Animals as the Vapours separated from Buxton-Water by boiling, p. 237, 238, 239. Vol. I.

Having found that Animals could *not live*, nor Substances *burn*, in the permanent Vapour which rises spontaneously from Buxton-Water, I enquired, whether *Seeds would live or grow exposed to this permanent Vapour, instead of Air*. Also as some of the Properties of this permanent Vapour were found to be like those of *Air united with Phlogiston*, and *Air altered* by Respiration and Putrefaction, the Effects of Seeds of Plants confined in Air thus *altered* were at the same Time investigated.

Exper. XXXII. In the Month of March, 1783, seven Garden-Dishes of the same Size were filled with Earth from a Garden: in one half of each of these Dishes were sown the Seeds of *Garden-Cresses*, and in the other half those of *Mustard*, in as exactly the same Manner as possible. Each of these Dishes were then put into a much larger Dish, capable of holding an inverted Receiver containing four or five Quart Measures of permanent Vapour, and Water sufficient to prevent the in-

cluded

cluded Vapour from mixing with the Air of the Atmoſphere.

Theſe Receivers, which were Glaſs-Bells, were inverted over the Diſhes containing Earth and Seeds by immerſing the ſmaller Diſhes in the larger ones in a Tub of River-Water of the Heat of 54°, and while immerſed, placing the Receivers of permanent Vapour within theſe larger Diſhes; by which Means an inverted Receiver containing a Pot of Earth ſown with Seeds ſtanding within a large Diſh with Water interpoſed between the Atmoſphere and permanent Vapour included in the Receiver was brought out of the Water, and expoſed to the Atmoſphere. Care was taken that the Water ſhould not be in ſuch a Quantity within the Receiver as to keep the included Pots under Water.

The Receiver N° 1. contained *atmoſpheric Air*.

——— N° 2. was nearly filled with the *permanent Vapour that extricates itſelf ſpontaneouſly from Buxton-Water*.

——— N° 3. held Air *altered*, to the Teſt of nitrous Gas, as much as poſſible (*u*), by the

(*u*) The joint Dimenſions of two Meaſures of this *altered* Air with one Meaſure of nitrous Gas, after Mixture, were two Meaſures and $\frac{7}{9}$; and it could not be further *altered* by Reſpiration, although ſeveral Animals were included in this Parcel of Air after being changed in this Manner and heated to 70°.—They lived a few Seconds, ſometimes half a Minute therein.

Reſpira-

Respiration of Mice, and which had been previously passed repeatedly through a large Quantity of Water.

The Receiver N° 4. contained Air, to the Test of nitrous Gas, *completely changed* by the *Putrefaction* of animal Matter (*x*), and freed from fetid Matter and Gas by transferring it several Times through Water.

———— N° 5. was *Air* wholly *saturated with Phlogiston*, detached during the Decomposition of Iron and Sulphur mixt together, and deprived of a sulphureous Smell occasioned probably by the Admixture of volatile vitriolic Acid, or of a permanent Vapour of the hepatic Kind, by Transmission through Water.

———— N° 6. was filled with *Oil of Metals* precipitated from Iron by diluted vitriolic Acid.

(*x*) I procured a large Quantity of Air so *altered* by Putrefaction that no Part of it combined with nitrous Gas, by exposing animal Matter, in Glass-Bells inverted in Water, to the Heat of a Dunghill covered with a Melon-Frame.

I once placed these inverted Glasses with animal Substances to ferment in a Hot-house; but very disagreeable Consequences happened :—the Fermentation was so rapid in this Exposure as to expel such a Quantity of fetid Vapour through the Water in the Dish interposed between the included Air and the Atmosphere, as to be intolerable to either Plant or Animal.

The

The Receiver N° 7. was a Pot of Earth and Seeds exposed to the *open Air*.

The Situation of these inverted Receivers was a large Room in which they were exposed to the Light of the Sun, or of Candles constantly, excepting about six Hours every Night; and in a Heat that was variable between 46° and 54°.

In the Space of seven Days the Seeds of the *Cresses* could be just perceived *coming up* in N° 1. and N° 7.

In a Fortnight further the *Cresses* had grown two Inches in Height in N° 1. and N° 7., but there was not a Sign of Vegetation in the other Receivers, or of Growth of the Mustard in N° 1. and N° 7. The Earth of N° 7. being dry was moistened with River-Water.

In another Week's Time the *Cresses* in N° 1. had *grown taller*, and looked *healthy* and *vigorous*. In the other Receivers there was no Appearance of Vegetables, or in the Parts of the Pots sown with Mustard in N° 1. and N° 7.

In a Week further the Cresses in N° 1. had not grown taller, and were in a *languid State* while those of N° 7. in the open Air had every *Sign of Health*. The Seeds had not come up in the other Receivers.

The Seeds of Cresses sown and contained under the Receivers N° 2, N° 3, N° 4, N° 5, N° 6. not having come up after being in the Earth five Weeks, and having vegetated and appeared in

N° 1.

N° 1. and N° 7. in one Week, although all theſe Numbers were under ſimilar Circumſtances of Expoſure to Heat, Light, Preſſure, &c. the included Pots of N° 2, 3, 4, 5, and 6. were withdrawn from under the Receivers and expoſed to the open Air, under otherwiſe the ſame Circumſtances as before. The Earth on withdrawing theſe Pots from under the Receivers was obſerved to be ſufficiently humid for Vegetation.

After ſix Days Expoſure I diſcovered the Creſſes juſt appearing through the Earth in all the Diſhes that had been under the Receivers; after which Time they continued to grow, and there was *an abundant Crop* of this Species of Plant, but not a Plant of Muſtard appeared. It was obſerved however, that the Creſſes were eſpecially luxuriant under N° 3. The Taſte of theſe Plants was the ſame as when they grow expoſed to the Atmoſphere.

This Experiment was repeated when the Atmoſphere was warmer, in April following, and with the ſame Event; namely, the Seeds of Creſſes only grew in the Receiver N° 1. in a weakly Manner, and in the Pot N° 7. in the ſame Manner in general for a certain Time as in the open Air: but upon Expoſure of the Pots of Earth that had been included in the Receivers N° 2, N° 3, N° 4, N° 5, and N° 6. to the Atmoſphere, there was a plentiful Produce of them; and not a Plant of Muſtard appeared.

I do

I do not know why the Seeds of Muſtard did not grow in this Experiment as well as the Seeds of Creſſes, unleſs the Heat to which they were expoſed was not ſufficient for Vegetation, or that their *Living-principle* was injured or deſtroyed before they were ſown.

I believe Homberg, Mr. Boyle, Muſſenbroek, Boerhave, Dr. Derham, and Cygna, among ſeveral other Authors have affirmed, that Seeds do not grow in Vacuo. Seeds ſown very deep in the Ground are obſerved by the Huſbandman not to come up, and *it is here ſhown for the firſt Time, as far as I know, that Seeds will not grow in the permanent Vapours under the Receivers* N° 2, N° 3, N° 4, N° 5, N° 6. in the above Experiment, any more than in exhauſted Veſſels. Alſo it is rendered extremely probable by the Event of this Experiment, that Eggs cannot be hatched in the permanent Vapours in which Seeds do not grow.

In the above Experiment it is ſhewn that Seeds will grow in confined Air, but that, after the Plants have vegetated therein a certain Time, the Air becomes then unfit for Vegetation, and unleſs freſh Air be applied the Vegetables die.

Mr. *Scheele* found Peaſe to ſtrike Root and to grow in a ſmall Quantity of confined Air, but after a Fortnight they would grow no longer:— this confined Air was neither increaſed nor diminiſhed; one-fourth of it appeared to be Gas and the reſt extinguiſhed Flame. In this Experiment

riment of Mr. Scheele, perhaps, the Gas was ſeparated from the Peaſe during ſprouting, or as the Author ſuppoſes, a Portion of the Air was converted into Gas, and the Air by Union with Phlogiſton or ſome other Means being *altered* extinguiſhed Flame. The Air was diminiſhed one-fourth in Volume, ſuppoſing the Gas to have been added from the Seeds; and the Roots in this Experiment do not appear to have either abſorbed Air, or to have ſeparated it.

The permanent Vapours N° 2, N° 3, N° 4, N° 5, and N° 6. in my Experiment, moſt probably operate upon Seeds by ſome *negative Quality*, as well as many of them do upon the *Lungs* of living Animals, and as a *Vacuum* does upon Seeds and Reſpiration. The Principle of Life appears to have prevented the Seeds in the above Experiment from putrefying, for they were otherwiſe under favourable Circumſtances for undergoing the putrefactive Fermentation. But it is not the Living-principle, or not that Power alone that occaſions Seeds to reſiſt Putrefaction in exhauſted Receivers, becauſe no Kind of *dead* Matter will grow putrid in *Vacuo*.

The Principle of Life not only exiſts in animal Subſtances "devoid of apparent Organization," as in Eggs, according to the Obſervations of Mr. John Hunter; but in unorganized vegetable Matter as ſhewn in the foregoing Experiment.

I con-

I consider this Experiment as affording a very curious and interesting Fact relating to vegetable Life. It has been suggested that it furnishes a a Ground for the Preservation of Seeds under Circumstances in which they would *putrefy* or *die*.

Having learned the Effects of the above-mentioned Species of permanent Vapour on *living* Seeds, I proceeded to inform myself concerning their Effects on *living Plants*.

Exper. XXXIII. *Water-Cresses*, *Brooklime*, and *Garden-Mint*, separately, in short Jars filled with Earth and Water, were at the same Time introduced within each of the Receivers of permanent Vapour of the last Experiment, namely, N° 1, N° 2, N° 3, N° 4, N° 5, and N° 6. in the same Manner in which the Pots containing the Seeds were there placed within them, and exposed to the same Quantity of Light, and Degrees of Heat as there mentioned. These Plants were also placed in the same Exposure in the open Air, and distinguished by being marked N° 7.

The Plants in the Receivers looked very healthy and *grew* for about 14 Days, mean while those in the open Air appeared in a *less flourishing State*; but at this Time N° 7. continued *vegetating as before*, and N° 1, N° 2, N° 3, and N° 4. were either *very languid*, or in a dying Condition, and N° 5 and N° 6. were in *Health*.

A few Days after this Time all the Plants were *dead* excepting those of N° 1 and N° 7. In

N° 1. they had grown to ſuch a *Length* although they appeared *ſickly*, that the Receiver was too ſmall for them to ſhoot longer. The Plants were now all withdrawn.

To the Teſt of nitrous Gas, as well as Flame, the permanent Vapours were not altered, excepting the Air in N° 1. which required leſs Phlogiſton to ſaturate it than before, and it extinguiſhed Flame. The weakly State of the Plants in N° 7. in the open Air was probably occaſioned by the open Air being too cold for luxuriant Growth, or by ſome other Circumſtance unfavourable to vegetable Life and Growth not underſtood. The Extinction of Flame by N° 1. was probably either occaſioned by the Putrefaction of ſome Leaves, or of the Water of the Receiver, or by ſome Alteration occaſioned by the Vegetation of the Plants.

This Experiment ſhews, that Plants grow leſs luxuriantly but for a much longer Time in a Receiver of common Air than in any of the other five Receivers of permanent Vapours examined in this Experiment; for Plants, no more than Animals, cannot live long without a freſh Supply of Air, although the Changes produced by Plants on Air, by which it is rendered unfit for Vegetation be not inveſtigated. Dr. Prieſtley found Plants grew when expoſed to that inflammable Vapour called Oil of Metals, inſtead of Air, for ſeveral Months. I have ſeen no Experiments

ſhewing

ſhewing that they vegetate in the permanent Vapours in the Receivers N° 2. and N° 5: nor perhaps in the Air of N° 3. and N° 4. ſo intirely or conſiderably *altered* by Reſpiration and Putrefaction.

Happening to leave the Receiver N° 6. of *Oil of Metals* ſtanding in Water, I was ſurprized to find a Day or two after the Plants were withdrawn, that Water had roſe conſiderably within it, and after ſupplying the Diſh in which it ſtood inverted with freſh Water, in a Day or two further this Receiver was three-fourths full of Water. I could aſſign no Reaſon for this great and ſudden Diminution of the Volume of Oil of Metals, but by ſuppoſing a Decompoſition had taken Place; however upon Trial the Reſiduum was as inflammable as before this Alteration of Bulk. It ſuffered no further Decreaſe of Bulk by ſtanding three Months longer.

Oil of Metals has been found by Dr. Prieſtley (*y*) to loſe its Inflammability by long ſtanding in Water, and the Reſiduum extinguiſhed animal Life and Flame; and that by Agitation in Water it may be made reſpirable. It becomes then a Queſtion whether the above Diminution of Bulk of Oil of Metals was not occaſioned by a partial Change of this Subſtance into Air unfit for Inflammation and Reſpiration, which being

(*y*) Exper. and Obſerv. on Air, Vol. I. p. 59.

10 or 12 Times specifically heavier than Oil of Metals, may account for this Phenomenon; and be in too small a Quantity to prevent the Inflammation of the remaining Oil of Metals with which it was mixed.

Exper. XXXIV. On the 11th of December, 1782, Plants of the same Species were included in the Receivers of permanent Vapours as in the last Experiment; and of the Kind there marked N° 1, N° 2, N° 5; and were also exposed to the open Air in the same Manner as N° 7. in that Experiment.

During the Time of this Experiment the Heat of the Atmosphere to which the Plants were exposed was 36° to 44°.

The 14th of this Month the Plants in the Receivers all looked healthy, and had *grown a little*, but those in the open Air N° 7. were in a *languid* State.

On the 23d of December the Plants in N° 2. and N° 5. were in a *luxuriant State* of Vegetation, having many additional Shoots and Leaves, and being grown taller and the Leaves broader than when first introduced; so that the Receivers N° 2. and N° 5. containing those Plants, appeared almost *filled with green Leaves*, while those of N° 1. continued growing, but not luxuriantly; and the Plants N° 7. in the open Air were in a *weak*, or even *dying State*.

The

The 27th of this Month the Plants in N° 2. and N° 5. were all either in a *languiſhing*, or dying State; thoſe of N° 1. were *growing* as before, and the Plants N° 7. were *not quite dead.*

January 24th, 1783. The Plants in N° 2 and N° 5. were all either *languiſhing*, or apparently dead. In N° 1. the Vegetation continued, but the Plants did but look *weakly*; the Stalks being ſmall and the Leaves of a leſs Size than natural, and of a pale green or yellowiſh Colour. The Plants in N° 7. in the open Air were quite dead.

On February the 8th following, the Plants in N° 1. were grown ſo *long* that the Receiver was too ſmall for them, but otherwiſe they appeared extremely *unhealthy*;—thoſe in N° 2. and N° 5. were *dead*, excepting a Stalk or two of Mint that had put out many lateral *Needle-like white Fibres.*

Upon Examination, the permanent Vapour of N° 2. and N° 5. to the Teſt of nitrous Gas, was not altered;—that of N° 1. was not examined.

The Event in general of this Experiment is not different from the former Experiment. For it appears in this Experiment that Plants lived, and flouriſhed about 17 *Days* in the permanent Vapour that ſeparates itſelf from Buxton-Water, and Air ſaturated with Phlogiſton, or, to the Teſt of nitrous Gas, totally *changed* by a Mixture of Iron-Filings and Sulphur; and then languiſhed, and gradually died;—that they lived and grew, but not vigorouſly, in the Receiver of common Air *two*

Months or longer; and that they *died in a few Days* in the open Air.

In this Experiment the Plants died in the open Air, probably, on Account of its not being of a ſufficient Degree of Heat.

The latter End of March, 1782, the following Experiment was made to aſcertain the general Effects from Plants of Mint expoſed to the permanent Vapour that riſes ſpontaneouſly from Buxton-Water: in particular to know whether there was any Reſemblance between this permanent Vapour and Air *altered* by Reſpiration and Putrefaction, and Air *changed* by, or *combined* with Phlogiſton.

Exper. XXXV. Three four Ounce Phials containing River-Water and Sprigs of *Garden-Mint*, were introduced within a wide Jar that was filled with two Pint Meaſures of *this permanent Vapour of Buxton-Water* and one Pint of River-Water, through a Tub of the ſame Water. For want of a Jar ſimilar to the above one, a four Ounce Phial containing two Sprigs of *Garden-Mint* were placed within a Jar that held ten Ounce Meaſures of *Air of the Atmoſphere* and two Ounces of River-Water.

Theſe two Jars ſtanding inverted in Diſhes of River-Water were placed in the ſame Expoſure, in a Room the Heat of which was variable from 44 to 52 Degrees, along with three four Ounce Phials

Phials containing Sprigs of Garden-Mint expoſed to the Atmoſphere.

In five or ſix Days the Plants in the permanent Vapour of Buxton-Water were in a *luxuriant State*; for the Leaves were *broader*, of a *darker Green*, and more in *Number* than thoſe included in the Jar of common Air, or expoſed to the open Air.

In ten Days further, the Plants in the confined Air, and in the open Air were grown *taller* than thoſe in the Jar containing the permanent Vapour of Buxton-Water, where they had made no Progreſs in Growth ſince the laſt Report, but looked very *healthy*.

On the Morning of the *ſeventeenth Day* of this Experiment all the Plants of Mint included in the permanent Vapour of Buxton-Water were found to have died during the preceding Night; for their Stalks were bent as if broken near the Neck of the Phials; the Leaves were flaccid and blackiſh, inſtead of a deep green Colour which they had the Evening before. After remaining 12 Hours longer in this Jar they were withdrawn, and found quite dead; even in a mucilaginous State.

The Plants in the open Air and in the Receiver of common Air *grew well* ſeveral Weeks *longer*; after when they were removed; and at that Time the Sprigs of Mint in the confined Air were in a *weakly State*, and had an unhealthy Appearance.

The permanent Vapour of Buxton-Water in which the Plants were included in this Experiment was mixed with nitrous Gas ſeveral Times in the Courſe of this Experiment, without the leaſt Diminution in the Sum of the Dimenſions of theſe two Subſtances, ſeparately, being perceived after Mixture.

This Experiment was repeated by introducing Plants into the Receiver of permanent Vapour of Buxton Water above-mentioned in this Experiment in May, 1782, with nearly the ſame Iſſue: for the Plants grew *more luxuriantly* for a few Days in this permanent Vapour of Buxton-Water than in confined Air, or in the Atmoſphere, but *died* in leſs than a Fortnight in this permanent Vapour of Buxton-Water, *lived* ſeveral Weeks in a *weakly or unhealthy State* in confined Air; and at the ſame Time lived, and were as *healthy* as theſe Plants uſually are in the Phials of Water expoſed to the open Air.

It appears then from the three laſt related Experiments, that vegetable Life cannot long be continued in any of the permanent Vapours contained in the Receivers N° 2, N° 3, N° 4, N° 5, and N° 6. See Exper. XXXII. this Vol.—that Plants live a much longer Time in *confined Air* than in theſe permanent Vapours, but become unhealthy, and afterwards die, while the ſame Species of Plants expoſed to the Atmoſphere under otherwiſe like Circumſtances to thoſe included in the Receivers grow

grow and are healthy; provided the external Air be of a proper Temperature. The Plants were affected by these permanent Vapours in the Receivers upon the same Principle, if not because they are all the same Substances, excepting that of N° 6.: for they lived nearly the same Space of Time, vegetated with about the same Degree of Vigour, and died with the same Appearances;—if the permanent Vapours suffered any Alteration this Change was, perhaps, alike in all of them. These included Vegetables appear to have been killed by a *negative Quality* of these permanent Vapours, rather than by any *positive noxious Property*; and on the same Principle that it has been shown, p. 52. 57. 75. 80. this Vol. that Animals are deprived of Life by these Substances, and that Vegetables and Animals die in Vacuo, or in extremely rarefied Air. For the Plants did not die in these permanent Vapours so suddenly, or with the same Phenomena as when the Death of Animals and Vegetables is occasioned by permanent Vapours that kill Plants by positive Qualities, as volatile sulphureous Acid, Gas, &c.; but slowly in the same Manner as imperfect Animals die in these permanent Vapours, and Plants and these Classes of Animals die in exhausted Receivers. Further; Plants live in Receivers of these permanent Vapours mixed with a small Quantity of Air, probably, as long as they would live in the same Quantity of Air alone. Also at Buxton in the

Room where there is the Bath, and in which the Air muſt neceſſarily be mixed with the permanent Vapour that ariſes ſpontaneouſly from the Bath, Moſs grows in a luxuriant Manner upon the Stones of the Wall near the Window.

Plants do not die in Receivers of theſe permanent Vapours in Conſequence of any Change in the Qualities of theſe Vapours operated by Vegetation, becauſe after Plants have lived and died in them freſh Plants being introduced lived as long, and with the ſame Degree of Health as the former.

Vegetables live much longer than even the moſt imperfect Animals in the above permanent Vapours, or than theſe Animals in exhauſted Receivers; not only becauſe they carry into theſe Receivers of permanent Vapour a Quantity of Air adhering to their Surfaces, and have a Supply of Air for a Time from the Water in which the Receivers ſtand inverted, and the Earth in which they grow; but becauſe Plants, from the Nature of their Conſtitutions, can live longer without Air than, I believe, the moſt imperfect Animals: and Animals bear the Air-Pump in Proportion to their imperfect State. So that in Truth, although Vegetables lived even in a vigorous State in theſe permanent Vapours between two and three Weeks, they are as unfit for ſupporting vegetable as animal Life; and it is for the above Reaſons that we can underſtand why

Plants

Plants die in confined Air long before it is wholly changed, to the Teſt of nitrous Air, and yet freſh Plants live in this Air for a Time in which Plants have died, and in the permanent Vapours in the above Experiment.

Living Vegetables, under certain Circumſtances, excrete Air much more pure than atmoſpheric Air (z); and under certain Circumſtances alſo, probably, injure, or render it improper for ſupporting animal Life and Flame, and alſo, perhaps, for vegetable Life. But neither the Effects of Air, thus excreted and altered, on vegetable Syſtems, nor all the Circumſtances in which this Excretion of Air and this Change happens, are well underſtood. Probably, however, in the preceding Experiment the Excretion of pure Air either did not take Place, or it was again vitiated by the vegetable Functions, for it was not apparent to the Teſt of nitrous Gas: and on Account of the Difference of the Powers of Plants at different Times in ſeparating pure Air, in vitiating Air, and the different Quantities of Air adhering to the Plants introduced within the Receivers, and contained in the Water and Earth to which they are expoſed, as well as the accidental Injury of the included Air from the *dead* Parts of Plants, *Inſects*, and *Animalcules* in Water, the Length of Time in which a Plant will live in the above per-

(z) Phil. Tranſ. Vol. LXXII. P. ii. p. 426.

manent

manent Vapour, under the above Circumſtances, is more various than the Length of Time in which an Animal will live therein.

Plants live a ſhorter Time in nitrous Gas than in Air ſaturated with the Phlogiſton of nitrous Gas; becauſe, perhaps, the nitrous Gas combines with the pure Air as faſt as it is excreted, thereby robbing the Plant of the Air that would ſupport it a ſhort Time, and alſo by combining with the Air accidentally contained in the Receivers in which the Plants are included.

Dr. Prieſtley found (Exper. and Obſ. Vol. I. p. 61.) that Plants grew ſeveral Months in inflammable Air precipitated from Zinc, and alſo from Oak, without diminiſhing at all, or only very little, its Inflammability; probably, they would not have lived ſo long had not the inflammable Air been mixt with a Portion of common Air.

Although the permanent Vapours above-mentioned are as unfit for ſupporting vegetable Life as extremely rarefied Air, yet during the ſhort Space of Time Plants lived therein they manifeſted, for a few Days, Signs of their Functions being performed with an extraordinary Degree of Vigour; which State of high Health did not proceed from theſe permanent Vapours affording more Nouriſhment than Air, but, I conceive, might ariſe from the permanent Vapours to which they were expoſed proving a Stimulus to the vegetable Powers; or they might occaſion more

luxuriant

luxuriant Growth than in common Air, under ſimilar Circumſtances, on Account of their deſtroying in a ſhort Time the Inſects or Animalcules in the Water, Earth, or upon the Surface of the Plants, which being killed would afford Mucilage,—the moſt nutritious Food of Plants;—although theſe Vapours were unfit for continuing vegetable Life, they forwarded their Growth until the Stock of Air was rendered improper for Vegetation, or was abſorbed; after when, the Plant languiſhed and died like Animals and Plants in exhauſted Receivers. This luxuriant Growth may be compared to the Struggles of imperfect Animals for a ſhort Time after being included in theſe permanent Vapours; which are ſucceeded by a torpid or motionleſs State for ſome Time before Death enſues. It may however be queſtioned whether permanent Vapours, operating as a Stimulus in the Manner above-mentioned, mixt with a Quantity of Air ſufficient for vegetable Life, may not render Air more ſalutary both to Animals and Vegetables.

It has been found firſt by Dr. Prieſtley, and afterwards by various Experimenters, that upon ſome Occaſions Vegetation has the Power of meliorating Air rendered impure by Reſpiration, Inflammation, Putrefaction, and Phlogiſton, though that Alteration has not been well underſtood. I have endeavoured to explain the Effects of Ve-

getation

getation upon ſoul Air more fully than has been hitherto done, p. 82, Note (*e*), Vol. I.

The three preceding Experiments ſhew the Reſemblance between the permanent Vapour that ſeparates itſelf from Buxton-Water and Air *altered* by Reſpiration, Inflammation, and Putrefaction, in their Effects upon the Life of Plants: it was therefore next enquired, whether living Vegetables have the Power of decompoſing the permanent Vapour that ariſes from Buxton-Water, or of changing Receivers of this Subſtance partially or wholly to the State of Air.

Exper. XXXVI. Garden-Creſſes, Water-Creſſes, Brook-lime, Common, and Pepper-Mint, in a very healthy State, were introduced into two Ounce and four Ounce Phials filled,

Firſt, With the permanent Vapour that ſeparates itſelf from Buxton-Water.

Secondly, With *Air altered*, as much as poſſible, to the Teſt of nitrous Gas, by Reſpiration; and previouſly transferred repeatedly through Water.

Thirdly, With *Air changed* entirely by being united with the inflammable Principle, by Expoſure to a Mixture of Iron-Filings and Sulphur.

Fourthly, With *Air* totally *altered*, to the Teſt of nitrous Gas, by Expoſure to the putrefactive Fermentation.

Fifthly, With common Air.

The Plants were paſſed into the Phials through River-Water and corked while inverted in this

Water, leaving always a ſmall Quantity of Fluid between the Cork and the Plants.

Theſe Phials containing Plants, and Phials of the above permanent Vapours without Plants, were repeatedly expoſed to *Light*, to the *direct Rays of the Sun*, and *excluded* from Light, for two, five, and ten Hours; and to the natural Light and Darkneſs for one, two, three, and five Days of the Month of March, 1783.

The Heat of the Air during the Expoſure of theſe Phials was in the Sun about 56° to 60°, otherwiſe it was from 36° to 50°.

After ſtanding in the above Circumſtances one Meaſure of included permanent Vapour was mixed with one equal Meaſure of nitrous Gas, but not the leaſt *Diminution* of the Bulk of the two Subſtances was obſerved, or any *turbid Appearance* with the four firſt permanent Vapours, excepting upon one Occaſion, which was as follows.

The very firſt Time Plants were ſubjected to this Experiment was at Three, P. M.; when a one Ounce and a half Phial of the above *permanent Vapour of Buxton-Water* containing a ſingle Sprig of *Pepper-Mint* and a ſmall Bunch of *Garden-Creſſes*; and another Phial of the ſame Size filled with Air *changed* as much as poſſible by Reſpiration, containing the ſame Kind and Number of Plants as the other Phial were expoſed to the direct Rays of the Sun;—the Afternoon being clear

for three Hours. At this Time a Part of each of theſe two Phials of permanent Vapour being mixed with nitrous Gas, there was a *yellowiſh Colour* produced ſucceeded by Tranſparency, and inſtead of the joint Dimenſions of theſe Subſtances ſeparately, being as before Expoſure to the Light and Plants two Meaſures and one-tenth, they were one Meaſure and one-fourth with one; and inſtead of the other Mixture being, as before this Experiment, one Meaſure and nineteen-twentieths, it was at this Time one Meaſure and one-ſeventh. So that one of theſe Species of permanent Vapour was as pure as common Air, and the other about as pure, perhaps, as Air in which a Candle has burnt out.

Theſe Phials with the Plants, permanent Vapours, and River-Water that contained the permanent Vapour uſed in this Experiment, ſtood the following Night within Doors and in the Morning were mixed with the ſame Parcel of nitrous Gas as before, but there was no turbid Appearance on Mixture a ſecond Time, and upon Admeaſurement the Dimenſions of the Mixture with the permanent Vapour of Buxton-Water was nearly the ſame as before the Experiment, and with the other permanent Vapour was reduced from two Meaſures to one Meaſure and two-thirds. So that the permanent Vapours within the Phials had returned in the Courſe of the Night to the ſame State, or nearly to the Condi-

tion,

tion, they were in before they were expoſed to the Influence of *Vegetation* and *Light*.

The Plants looked healthy in all the Phials of permanent Vapour.

The atmoſpheric Air after Expoſure to the Action of Vegetation and Light was not either uniformly ſo much better, or ſo much worſe than before this Expoſure, as to be able to pronounce whether the Expoſure of it to the vegetable Functions and Light had produced any Change.

I have in a former Part of this Work obſerved that we are not authoriſed to conclude, from any Experiments hitherto publiſhed, that Vegetation changes Air rendered impure by Reſpiration, Putrefaction, &c. and Compound of Air and Phlogiſton to the State of Air; and that it is moſt probable when Air combined with Phlogiſton and injured by various Means has been expoſed to the Influence of living Vegetables, and Air was found in the Receivers or Veſſels after this Expoſure to Vegetation, it was not produced by any Decompoſition or other Change of the included permanent Vapour, but was *ſeparated* from the living Plants and was *added* to the included permanent Vapour. This *Addition* of pure Air, perhaps, has eſcaped Notice, becauſe at the ſame Time that Plants ſeparated this pure Air, they, as well as the Water in the Veſſels in which the Vegetables were expoſed, might abſorb ſome impure Air. When no Alteration was produced in the State of

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the permanent Vapour to which Vegetables were expoſed, I ſuppoſe no pure Air was excreted. And when the included Air was rendered more impure, that either the Fermentation of a *dead* Part of the Vegetable, or ſome Operation of the *living* Vegetable itſelf at particular Times, or *Animalcules* in the Water and upon the Plants produced this Effect.

In the above Experiment it is probable, either that the permanent Vapour of Buxton-Water, and Air *altered* as much as poſſible, to the Teſt of nitrous Gas, by Reſpiration, is a Compound of Air and ſome other Subſtance, perhaps Phlogiſton, ſuppoſing the Air found after expoſing this permanent Vapour to Vegetation to have been produced by Decompoſition; or that pure Air was excreted by the vegetable, and ſome of the permanent Vapour of Buxton-Water was abſorbed by the Plants. The Air thus produced was ſoon either vitiated by the *Plants*, *Animalcules*, or *dead animal or vegetable Matter* within the Phials, or was abſorbed by the Water or the Plant; and the permanent Vapour firſt abſorbed by the Vegetable was again ſeparated.

The next Subject of Enquiry was, whether the permanent Vapour that extricates itſelf from Buxton-Water has any, and what Power in preventing, impeding, or promoting Fermentations.

I. *Saccharine*,

II. *Vinous*, and

III. *Acetous Fermentations*.

I am

I am not able to relate any ſatisfactory Experiments or Obſervations to ſhew whether Subſtances can be at all converted into *Sugar*, *Wine*, or *acetous Acid*, or are more ſlowly, or ſpeedily changed into theſe Things, included in this permanent Vapour of Buxton-Water inſtead of Air. The following Experiment is not deciſive, becauſe this permanent Vapour was not applied in ſufficient Quantity, and the Temperature of the external Air was too various, and frequently unfavourable to the Production of fermentative Proceſſes.

Exper. XXXVII. A Phial containing half an Ounce of Syrup of Violets, a quarter of an Ounce of Water, and an Ounce and a half Meaſure of the permanent Vapour that ſeparates itſelf from *Buxton-Water* was corked, and expoſed in an inverted Poſition for four Months to the Sun on the Outſide of the Window of a Chamber, or near the Fire of a Sitting-Room in the Day-Time, and in the Night generally was placed in a Room of a temperate Heat. During this Expoſure the Degrees of Heat were included between 40 and 100.

The Syrup changed to a brown Colour, but did not manifeſt any Signs of Fermentation, nor did it loſe in the ſmalleſt Degree its ſaccharine Taſte.

It is affirmed by ſome eminent Chymiſts, but I do not know on what Obervations, that Air is eſſentially neceſſary to the Production of Wine

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from Sugar, as well as to the other Species of Fermentation.

The ſubſequent Experiments will perhaps be deemed ſufficient to aſcertain the Influence of this permanent Vapour of Buxton-Water on the *mucilaginous* (*a*), and *putrefactive* Fermentation.

IV. *Mucilaginous*,

V. *Putrefactive Fermentations*.

Exper. XXXVIII. Two Phials of this permanent Vapour of Buxton-Water containing a Slice, in Weight about a Drachm, of Ox-Muſcle, and half a Drachm of Water were corked and placed inverted. A Thread was tied round theſe Maſſes of animal Matter, ſo that they could be withdrawn at Will.

Two like Phials of common Air with the ſame Quantity of animal Subſtance from the ſame Parcel, and the ſame Quantity of Water were alſo corked and inverted.

Theſe four Phials were expoſed in a Window to the Sun in the Month of September, 1782, within a Sitting-Room during warm Weather.

During the firſt three Days of Expoſure, ſome *Bubbles* were obſerved adhering to the Surface of the included animal Matter in each Phial; and

(*a*) There are two Stages of Putrefaction, the firſt produces Mucilage, the ſecond converts it into calcareous Earth, muriatic and nitrous Acids, and volatile Alkali.—Dr. Fordyce's Elements of Agriculture, p. 64, and Appendix, p. 3.

the

the Bulk of this Matter was enlarged. The animal Matter was then withdrawn from each of the four Phials, and all found equally in *a mucilaginous State*; and all of them alſo were rather *fetid*; ſo that the mucilaginous Fermentation had taken Place, and the putrefactive Fermentation was commencing.

Theſe Maſſes of animal Subſtance were then returned into the Phials and expoſed as before in the Sitting-Room Windows. During fourteen Days further, the Bubbles as before obſerved continued to be ſeparated, and many of them adhered to the Surface of the Muſcle and Water, and rather more abundantly in the Phials of permanent Vapour of Buxton-Water, than in thoſe of Air. The putrefying Subſtances *changed their Colour*, and were enlarged ſtill more in *Bulk*. The Corks upon being looſened to withdraw the putrid Subſtances, were expelled out of the Bottles, and an *Exploſion* accompanied their Expulſion. The included Muſcle from all the Phials was found to be extremely *looſe*, *ſoft*, and *ſtunk* intolerably.

This Experiment was repeated by including a Portion of the *Liver of a Sheep* within a Phial of this permanent Vapour of Buxton-Water, and another Portion in a Phial of *Air*, to the Teſt of nitrous Gas, totally *altered* by Lxpoſure to a Mixture of Sulphur and Iron; and a third Portion in a Phial of common Air.

In each of theſe Bottles were a few Drops of Water; and they were corked, tied over with wet Bladder, and placed inverted in a Sitting-Room for three Months, during the Winter 1782 and 1783. The ſame Phenomena occurred as in the firſt Performance of this Experiment, and after ſtanding the above Time the *Corks* were withdrawn while the Phials were immerſed in a Tub of cold Water;—immediately upon looſening and withdrawing them, Bubbles ruſhed copiouſly through the Water, which emitted a moſt fetid Odour, and the included animal Matter was forced out of them attended with an Exploſion, and appeared in fibrous Pieces or Shreds on the Surface of the Water.

The Phials, having thus emptied themſelves of the included Portion of Sheep's Liver in a putrid State, wereplaced inverted in Saucers of cold Water, within which Water roſe immediately juſt above their Necks; and in a few Days it occupied without any Variation in the Heat of the external Air, about one-fourth of the Space of each of the Phials.

I again repeated this Experiment in the following Manner. I collected at Buxton the permanent Vapour as it roſe from the Bath, p. 23. this Vol. frequently in Bottles that contained near four Wine-Pints. A Maſs, of about ſix Drachms in Weight, of Muſcle of a Calf was introduced into one of theſe Bottles filled with this permanent

Vapour

Vapour juſt after collecting it, and the Bottle was corked and preſerved inverted. Several Months after this Time, this Bottle was uncorked in cold Water;—upon drawing out the Cork there was an Exploſion, and a large Quantity of moſt inſupportably fetid Bubbles were diſcharged through the Water. The animal Matter included was completely putrefied, and the permanent Vapour in which it was included was extremely fetid.

The *Eels* in Exper. XVIII. p. 62. this Vol. were left to putrefy in inverted Jars ſtanding in a deep Diſh of Water. The Fermentation went forward in the open Air during the Summer 1783 pretty much alike in all of them, and the Water gradually roſe within them, ſo as to occupy one-third of their Contents in about three Months. During this Space of Time a large Quantity of green Matter collected in the Diſh of Water in which the Jars were inverted. I attributed this Diminution of the Bulk of the included permanent Vapours, partly to the Abſorption of the Gas ſeparated by the putrefactive Fermentation, but principally to the Combination of the permanent Vapour of Buxton-Water in one Jar, and the Air *altered* by Expoſure to Subſtances undergoing the putrid Fermentation in the other Jar, with the Water of the Diſh; becauſe this Water from its Expoſure to the Sun ſeparated its uſual Portion of Air in the Day-Time, and therefore more readily ab-

ſorbed the confined permanent Vapours. I was rather ſurprized however, in Conſequence of ſome late Experiments, to obſerve Water containing ſo large a Quantity of putrid Matter ſo full of Vegetables.

The preceding Experiment furniſhes abundant Proof, that the mucilaginous and putrefactive Fermentations go forward as ſpeedily in the permanent Vapour of Buxton-Water that riſes from the Bath, and in Air *altered* by Expoſure to Iron mixed with Sulphur as in common Air.

Subſtances during Putrefaction ſeparate Phlogiſton, inflammable Air, Gas, fetid Matter either in the Form of a permanent Vapour or of a Solid or Fluid diffuſed through the permanent Vapour to which the Subſtances attending it are expoſed; and if the fermenting Maſs be ſurrounded with Air, the Phlogiſton, probably, combines therewith and forms a Compound totally different from Air; frequently of late called phlogiſticated Air; by which Union the Bulk of the Air ſo combined is diminiſhed.

To the permanent Vapour included in the Bottles during this Experiment were added the above Subſtances extricated during the putrid Fermentation, hence upon removing the Preſſure by uncorking the Bottles Part of the included compreſſed Vapours, in Conſequence of their Elaſticity, ruſhed out of the Phials and occaſioned a Sound, and ſtill left the Veſſels full of permanent

nent Vapour, or nearly ſo. After ſtanding expoſed to the Action of Water a ſhort Time one of the Subſtances ſeparated by Putrefaction, Gas, being readily ſoluble in Water was diſſolved therein; which, together with the Combination of a ſmall Part of the other permanent Vapours with the Water, occaſioned the Water to riſe within the Phials after ſtanding a few Days uncorked inverted in Veſſels of Water. This Experiment ſhews that the Increaſe of Bulk of the Air in which Subſtances putrefy ariſing from the Extrication of the Vapours during Putrefaction, is greater than the Decreaſe happening in Conſequence of the Union of Phlogiſton and Air, and perhaps other Means; which Effect is not obſerved commonly, becauſe animal or vegetable Mucilage being ſet to putrefy in Veſſels inverted in Water, the Gas as well as ſome of the other permanent Vapours are diſſolved by the Water in which they are inverted.

This Experiment, perhaps, demonſtrates, that Putrefaction is eſſentially different from Inflammation (*b*). For Inflammation is the Operation of

(*b*) Dr. *M'Lurg* in his inaugural Diſſertation, at Edinburgh, 1770, conſiders Putrefaction to be a Variety of the Proceſs of Inflammation, as appears from the following Paragraphs, p. 34, 35.

43. Principia autem Putrefactionis facilius adtingere valemus, etiamque eorum effectum, credo, definire.

Sunt equidem Calor, Humor, atque Aër. Jam vero demonſtratum eſt, hæc omnia Phlogiſti Separationem imprimis

 promo-

of the chymical Attraction between the Principle of Inflammability and Air; but Putrefaction takes Place in the permanent Vapour that arises from Buxton-Water, and in Air saturated with Phlogiston, or in Air totally *changed* by Exposure to Iron and Sulphur mixed together, as appears in this Experiment, as well as in Air; therefore, Air is not essential to the putrefactive Fermentation, and consequently this Process is not Inflammation.

promovere: priora, dum Phlogiston quodammodo amissis deturbent; alterum dum idem ad ipsum trahat.

Num Causis, hoc Casu, effectum à communi alienum tribuimus? Haud necesse est, cum Phænomena quoque Separationi Phlogisti maxime conveniant.

44. Ad speciem tardæ separationis potius adtinet, cum in communi Atmosphæræ Calore, modico tantum Humore adjuto, succedat.

Dr. *Rutherford* in his valuable inaugural Dissertation at Edinburgh, 1772, adopts the same Opinion as that of Dr. *M'Lurg*, and which I believe was proposed by the learned Professor of Chymistry, Dr. *Black*.

Aër denique qui oritur ex Carne Putrescente Flammam similiter concipit & ex parte etiam fit Mephiticus. At certe Putrefactio Carnis haud magis hujus Separationi attribui potest quam carbonis Inflammatio. Immo plurima Putrefactionis Phænomena adeo lentam Inflammationem mentiuntur, ut veri simile videatur utramque ex eadem Causa varie Modificata pendere Phlogisti nempe varia Agitatione, dum è Corpore effugit & in Auras dissipatur. Et huc quidem respicit quod Aër in quo Caro putida evaserat, ex Parte in Mephiticum, ex Parte in aliam illam Speciem sicut ab Inflammatione, conversus est.—*Rutherford*, de Aëre Mephitico, p. 24.

Putre-

Putrefaction alſo goes forward in cloſe Veſſels with the ſmalleſt Quantity of Air; but a ſmall Quantity at leaſt of permanent Vapour of ſome Kind is neceſſary to this Proceſs, for it does not take Place in Vacuo. The Combination then of Phlogiſton, ſeparated from Subſtances putrefying, with ſurrounding Air is not eſſential to the putrefactive Fermentation, but is an accidental Concomitant, only taking Place when the permanent Vapour to which the putrefying Matter is expoſed is Air. According to the Experiments of Mr. *Boyle*, and Obſervations made concerning the Preſervation of animal and vegetable Subſtances by including Things, which are ſubject to putrefy, in the exhauſted Receiver, and excluding them from the Air by Oil, &c. it appears, that without certain permanent Vapours externally applied the putrefactive Fermentation cannot happen.

It is probable, however, that each Species of Fermentation has its peculiar efficient Cauſes, and there are various Kinds of Fermentations in living Bodies to which external permanent Vapour is not eſſentially neceſſary. For Inſtance, the purulent Fermentation goes forward frequently in the muſcular, and other internal Parts of the Body, as in the Subſtance of the Brain (*c*) where

(*c*) Were it neceſſary to ſtate the Evidences of this Fact, I could relate Caſes in which I have found upon Diſſection, Abceſſes in the Subſtance of the Brain.

there

there is no Air, or other permanent Vapour applied; and *Pus* is demonſtrably the Product of a peculiar Fermentation of animal Fluids, or of animal Matter deprived of Life;—one of the eſſential Requiſites of which is *Expoſure in a Cavity poſſeſſed of the Principle of Life* (*d*).

It

(*d*) The Change of animal Fluids into *Pus* is an Effect of which we have daily Examples in the Caſe of Extravaſations by Contuſions, Strains, Ruptures of Veſſels, Burns, certain ſtimulant Applications, as Cantharides, &c. Sir *John Pringle*, in the Appendix to his *Obſervations on the Diſeaſes of the Army*, ſeems to conſider *Pus* as a Matter depoſited in Conſequence of the Evaporation of the watery, or volatile Parts of the Serum. "I have (ſays this learned and induſtrious Obſerver) already obſerved, that the *Serum* of human Blood upon ſtanding but a little Time in the Furnace, becomes turbid before it grows offenſive, and then gradually drops a Sediment reſembling digeſted Matter, &c. May we not therefore conclude that the Serum is perpetually oozing into Ulcers, but from the Heat of the Part, and the natural Volatility of animal Fluids, it is all quickly evaporated, excepting this Matter that remains in the Sore, in the Form of Pus, and which is ſo requiſite to the Cure?"

I have frequently expoſed *Serum* of human Blood to Heat in the Manner juſt mentioned, and obſerved the turbid Appearance and Depoſition, but never before the Fluid was rather fetid, and the Depoſition continued to be made by ſtanding; ſo that, for aught I know, the whole of this Fluid may be converted into this Sediment, which has been ſaid to reſemble "digeſted Matter." The Nature of this Sediment remains to be inveſtigated, but it certainly is not formed, as this Author affirms, by Evaporation of the volatile or watery Part of the Serum, becauſe it happens when there

is

It has been been ascertained by Experiments that an Animal killed by a Shock of Electricity putrefies far more speedily than if it had been killed by some mechanical Injury of its Organs essential to Life. A Sheep killed by an electric Shock became so putrid in 24 Hours that it could not be used for Food.

This Fact suggested the following Experiment; to know, whether Animals killed by Exposure to the permanent Vapour that arises from Buxton-Water putrefy in the same Time that they do when their Death is occasioned by some Injury of a vital Part by mechanical Means.

Exper.

is no Evaporation, as in close Vessels; and it is connected inseparably with, if not merely formed by, the putrefactive Fermentation.

Nor is Pus formed in Ulcers, &c. by the Evaporation of the watery Part of the Serum, or animal Fluids, because the efficient Cause does not exist—there being no Evaporation in internal Abcesses; and because did it exist, mere Exhalation could not produce Pus.

Moreover, not only the Fluids in general or Serum in particular are convertible into Pus; but also the animal Solids and Muscles in general.

Nor can Pus be produced, by animal Fluids or Solids alone mixed with Pus, in close or open Vessels, subjected to the Heat of 96°, as I have found on Trial; but by this Means Putrefaction is speedily induced.

But I have formed Pus by exposing dead animal Muscle in a living Cavity that was producing Pus: viz. an Abscess among the Muscles of the Foot, Leg, &c.; and at my Request Mr. *Hey*, of Leeds, very obligingly repeated the Experiments I had made for this Purpose, without knowing the Event

Exper. XXXIX. I killed two lively Eels by ſevering their Heads from their Bodies with a ſharp Knife; and expoſed two Eels, of the ſame Size and equally alive as the former, in Receivers of the permanent Vapour that ariſes ſpontaneouſly from Buxton-Water, till they were dead.

After Death the Eels killed by the mechanical Means were more rigid than thoſe deſtroyed by the permanent Vapour.

The Eels killed by theſe two different efficient Cauſes were expoſed in Pint Jars filled with common Air, inverted in Water, to a Heat of about

Event I had experienced; and the Reſult of them was exactly conformable to that of my Experiments. The Converſion of animal Matter deprived of Life into Pus, by expoſing it to the Action of *living Cavities*, to which is neceſſary alſo, perhaps, an inflamed and purulent State, and the obvious Change of extravaſated Serum, &c. into Pus, as in the Caſe of Veſications, ſeems to ſhew that a Part muſt be *deprived of Life* before it is ſuſceptible of the purulent Fermentation. So were it poſſible for a Finger, or Toe, or a ſmall Animal, while *alive*, to be expoſed in a Cavity affording Pus, they would not undergo the purulent Fermentation, but deprive theſe Parts, or this Animal, of the vital Principle, and they would then be converted into Pus.

When a Part of the Body of a *living* Animal, is by any Means killed, it then undergoes one of two Species of Fermentation, according to the Circumſtances preſent, viz. it either mortifies or undergoes the putrid Fermentation, or it is changed into Pus; but what theſe Circumſtances peculiarly are have not been inveſtigated.

54° during the Day-Time, and 44° during the Nights.

It did not appear either from the Increaſe or Decreaſe of the Bulk of the included Air, or the Signs of Putrefaction in the confined animal Matter, that the putrefactive Fermentation proceeded differently in the Fiſhes killed by the above different Cauſes; but I would not infer from this Experiment that ſuch a Difference doth not happen upon other Occaſions.

The Queſtion next in Order in my Plan of Inveſtigation was, whether *diluted Solutions of Alkalies in Water*, aſſiſted by Heat and Agitation, were convertible into Magneſia, and any other Earth (*e*); whether diluted Solutions of neutral Salts with Alkalies for their Baſes, aſſiſted by Heat and Agitation, would be converted into

(*e*) *Boerhaave* ſays, that by repeatedly diſſolving alkaline Salt in Water, and evaporating this Solution to Dryneſs, there remains after each Evaporation a Portion of Earth; ſo that the whole Alkali may be changed into Earth, as mentioned by Van Helmont.

" All compound Salts, diſſolved in Water (ſo that the Solution ſhall contain a very large Quantity of Water in Proportion to the Salt) and expoſed to the Air are decompoſed, viz. in the *neutral Salts* the Alkali is converted into Magneſia, with which the Acid combines and forms an earthy Salt. In the earthy and metallic Salts the Acid flies off into the Air, and the Earth or Metal ſubſides, leaving the Water pure; hence River-Waters, &c. are purer than Spring-Water.—Elements of Agriculture by Dr. *Fordyce*, p. 42, 43.

neutral

neutral Salts with earthy Bases; and whether neutral Salts with earthy and metallic Bases might be decomposed by diluted Solution in Water, accompanied with Heat and Agitation, exposed to the permanent Vapour that extricates itself from Buxton-Water, and also Compounds of Air and Phlogiston, or Air wholly *altered* by Respiration and Putrefaction, in place of atmospheric Air; but I had only Time to determine a Part of this Question.

Exper. XL. I saturated a certain Quantity of Rain-Water with *blue Vitriol*, another Portion with *green Vitriol*, and a third Parcel with *white Vitriol*. These Solutions were filtered through Paper and came through the Filter quite transparent, but on standing a little appeared rather turbid, although they did not deposit a Sediment.

A Part of each of these Solutions was mixed with twenty Times its Bulk of Rain-Water, and stood in open Vessels exposed to the Atmosphere.

Another Part of each of these saturated Solutions was diluted with the same Quantity of Water as the first Part, in Quantity four Ounces of Solution diluted to this Degree, and was exposed in a large wide-mouthed Bottle to a Pint and a half Measure of the permanent Vapour which rises spontaneously from Buxton-Water, without being once in Contact with the Air of the Atmosphere; and being corked was preserved inverted.

A *third* Part of each of these saturated Solutions was diluted to the same Degree as the two former Parts, and preserved in Bottles quite full, and corked and inverted without having been in Contact with the Air of the Atmosphere.

I contrived to mix the saturated Solution with the Quantity of Water with which it was to be diluted without the diluted Solution being once exposed to the Atmosphere; by passing a small narrow Phial with a very straight Neck filled with the saturated Solution through a Quantity of Water in which was inverted the Bottle of Water with which it was to be diluted through the Mouth of the inverted Bottle, and as soon as it was landed therein, the inverted Bottle was corked, and by Agitation the saturated Solution contained in the small Phial passed within the inverted Bottle was mixed with the Water. With a little Care the Phial containing the saturated Solution may be introduced through Water within another Bottle without scarcely mixing at all with the Water through which it is passed.

All the above diluted Solutions were immediately *turbid*, and on standing deposited *Sediment* from a clear Fluid in about the same Quantity and in the same Time.

These diluted Solutions became again turbid, and deposited fresh Sediment on Exposure to Heat or further Addition of Water.

The Sediment depoſited was diſſolved by vitriolic Acid, and formed a metallic Salt which was decompoſed by Dilution as before.

If a little vitriolic Acid was added to the ſaturated filtered Solution of metallic Salt, it became immediately perfectly tranſparent, and was not decompoſed by *Dilution*, *Heat*, and *Agitation*.

Paper ſtained with Archill, and dried, was put into a Veſſel of Water in which was decompoſed ſaturated Solution of metallic Salt by the Dilution, without any Colour being induced that indicated Acidity.

It was inferred, that *to the Decompoſition of metallic Salts by Water the Application of Air is not eſſential*;—that if Air forwards that Decompoſition, the permanent Vapour that ſeparates from Buxton-Water does ſo alſo, or certainly does not impede it;—and that the Decompoſition depends eſſentially upon the Mixture with Water, and in Proportion to the Quantity of it, but may be promoted by Heat, and Agitation.

As the Acid was not denoted by the Archill in the Water it occaſions the Queſtion, whether it be ſome how deſtroyed, or be in too ſmall a Quantity to be perceived by this Teſt.

It has been already obſerved that upon the Principle of Decompoſition by Water may be explained many Phenomena of mineral, and other Waters; and, I believe, as I before obſerved, we are entirely, or principally indebted to Doctor

Fordyce

Fordyce for the Application of it to interpret this common Appearance of Nature.

The following Experiment was made to know whether this permanent Vapour of Buxton-Water be of an acid Nature.

Exper. XLI. A Shred of Paper ftained by dipping it in Archill, and afterwards dried, was paffed through Quickfilver into an eight Ounce Phial filled quite full, at the Bath, with permanent Vapour that rifes from Buxton-Water; and then was well corked and kept tied over with a wet Bladder.

Another Piece of this ftained Paper was in like Manner introduced within a half Pint Phial of *Gas* precipitated from Chalk, and was corked.

A third Piece of the fame coloured Paper was put into a Phial of common Air of the fame Size, with a little Water.

In a few Hours the Paper within the Phial of Gas was evidently changed of a reddifh Colour; and that in the others was purple as when firft introduced; nor did any further Change enfue on ftanding.

No Acidity in the permanent Vapour which feparates itfelf from Buxton-Water could be difcovered by this Teft, as was manifefted decifively by this Means in Gas; which furnifhes an additional Proof of its being a very different Subftance from Gas.

 Paper

Paper ſtained with the Juice of black Cherries is, I believe, a ſtill more ſenſible Teſt of Acidity than Archill; but that Subſtance could not, at the Time of this Experiment, be procured.

Exper. XLII. To know whether the permanent Vapour that ſeparates ſpontaneouſly from Buxton-Water be of an alkaline Nature, two Drachms of very freſh and very blue Syrup of Violets with as much Water were included in a five Ounce Phial of this permanent Vapour. The Vapour and diluted Syrup were agitated together, but neither immediately nor on ſtanding was any greeniſh Colour obſerved; therefore it was not of an alkaline Nature.

This Quantity of Syrup was introduced by filling the Phial with permanent Vapour, excepting half an Ounce of Water. The Phial was then expoſed oppoſite a Fire inverted in a Baſin of Water ſo as to rarefy the included permanent Vapour till it expelled half of the Water. This done, the Neck was ſtopped with the Finger and carried inverted into a Baſin containing Syrup of Violets, wherein the Syrup aſcended into the Phial equal in Bulk to the Water diſplaced by Rarefaction.

There are blue Juices of Flowers, as the *Flores Cyathi*, which are, I am told, more delicate Teſts of Alkaleſcency than the Juice of Violets; but they could not be obtained at the Time of this Experiment.

As

As there are both Acids and Alkalies in the Form of permanent Vapour, as Gas and volatile caustic Alkali, the two preceding Experiments were necessary.

Exper. XLIII. If the permanent Vapour that separates from Buxton-Water contain Phlogiston which flies off spontaneously, or is attracted by Sugar of Lead, it was apprehended it might be discovered by including a Piece of writing Paper that had been dipped in a Solution of this metallic Salt and afterwards dried, in an eight Ounce Phial of this permanent Vapour recently collected in the Bath.

After this impregnated Paper had stood some Time exposed to this Phial of permanent Vapour, no Colour, or Alteration of the Paper was observed; therefore no Phlogiston separated itself or was attracted.

I next exposed the permanent Vapour that separates from Buxton-Water to the Action of the following Acids, Alkalies, neutral, earthy, and metallic Salts; inflammable Substances, and Soaps, to see if it could be decomposed or combined in considerable Quantity with any of these Substances.

Exper. XLIV. Thin made five Ounce Phials containing three Ounce Measures of permanent Vapour that separates from the Bath at Buxton, inverted in deep Saucers of Water were exposed opposite a large Fire so as to expel the included

Water by the Rarefaction of this permanent Vapour; upon which they were removed, with the Mouth of each stopped by a Finger, into separate Basins of the following Substances:

1. Concentrated vitriolic Acid.
2. Diluted vitriolic Acid.
3. Concentrated nitrous Acid.
4. Strong marine Acid.
5. Acetous Acid.
6. Caustic vegetable Alkali.
7. *Spiritus Cornu Cervi.*
8. Solution of mild Alkali in Water.
9. Concentrated Solution of Nitre in Water.
10. Do. ——————— of Glauber's Salt
11. Do. ——————— of green Vitriol.
12. Do. ——————— of blue Vitriol.
13. Do. ——————— of white Vitriol.
14. Alcohol.
15. Oil of Olives.
16. Oil of Turpentine.
17. Solution of Soap of the Consistence of thin Jelly.

After the above Fluids had occupied the Place of the expelled Water during Exposure in a cold Room they were corked, or closed with Glass Stopples, and set to stand two Months in a Room of the Heat of about 50°; during which Time they were frequently agitated.

After these Fluids had stood the above Time, without any obvious Change of them, the Corks and

and Stoppers of the Phials containing them were withdrawn in Water; but this Fluid, of nearly the ſame Temperature as that of the Fluids when firſt included therein, roſe only in ſmall Quantity within the Phials.

Upon examining the permanent Vapour that had been thus expoſed to the above Subſtances with nitrous Gas it did not appear to have ſuffered the leaſt Alteration.

The Solution of Soap, which had been expoſed to the permanent Vapour in this Experiment, diſſolved in diſtilled Water without the leaſt Decompoſition.

I next attempted to aſcertain whether any, or what Quantity of the permanent Vapour that ariſes from Buxton-Water may be combined with Water.

Exper. XLV. This permanent Vapour of Buxton-Water in an inverted wide Tube, cloſed at one End, with 100 Times its Bulk of freſh Pump-Water, after ſtanding ſeveral Weeks in an inverted Poſition in a Jar of the ſame Water in a Temperature of the ſurrounding Air that was denoted by 46° to 54°, during which Space of Time it was agitated, did not appear diminiſhed.

When this Experiment was made with Lime-Water made of cold Pump-Water, the Bulk of permanent Vapour was rather increaſed.

This Experiment explains why Springs ſo frequently expoſed to the permanent Vapour called

Choke-Damp, may not be oftentimes combined therewith, viz. becauſe theſe Springs are already ſaturated, or nearly, ſo with Air.

The above Experiment is confirmed by the Reſult of Experiments III. and IV. p. 18 and 19. this Vol.

As the Water employed in the preceding Experiment was ſaturated, or nearly ſo, with Air, I concluded that Water ſo ſaturated would not combine with this permanent Vapour of Buxton-Water; therefore the following Experiment was made.

Exper. XLVI. Three Flaſks that held about 40 Ounces each were filled with Rain-Water immediately after it had been boiled more than three Hours.

Into N° 1. was introduced half a Drachm Meaſure of common Air;

—— N° 2. was paſſed the ſame Bulk of permanent Vapour that ſeparates itſelf from Buxton-Water.

—— N° 3. was introduced a like Quantity of Air combined with Phlogiſton or totally *altered*, to the Teſt of nitrous Gas, by expoſing it to a Mixture of Iron-Filings and Sulphur.

Theſe Flaſks were corked, and becauſe theſe Corks did not perfectly exclude the external Air from the Water within the Flaſks, they were alſo inverted in boiled Water.

In

In the Space of *two Days* the permanent Vapour introduced into all the three Flaſks was combined with the Water.

The three above-mentioned permanent Vapours were introduced in the Quantity of a Drachm Meaſure at a Time repeatedly as ſoon as each Drachm Meaſure was combined with the Water, for about three Months; after which Time the Whole, or Part of the laſt Portion of the permanent Vapour in each of the Flaſks remaining upon the Top of the Veſſel of Water for three Weeks, it was concluded the Water in the Flaſks was ſaturated with the permanent Vapour expoſed therein.

The Amount of the Portions of permanent Vapour combined with N° 1. was ſeven Drachms Meaſure; with N° 2. ſix Drachms Meaſure; and with N° 3. five Drachms Meaſure.

Upon a Repetition of this Experiment it appeared that three Pints of boiled River-Water, excluded from the Atmoſphere from the Time the Water began to grow cool, diſſolved, and was ſaturated by, ſeven Drachms Meaſure of the permanent Vapour that ſeparates from Buxton-Water; and at the ſame Time this Quantity of boiled Water diſſolved, and was ſaturated by, eight Drachm Meaſures of common Air; and eight Drachm Meaſures of *the Compound of Air and Phlogiſton*, formed by expoſing Iron-Filings and Sulphur to common Air, ſaturated this Quantity

of boiled Water of the ſame Parcel as the above. Three Pints alſo of this Parcel of boiled Water would diſſolve no more than eight Drachms and a half Meaſure of a Mixture of equal Parts of Air of the Atmoſphere and the permanent Vapour that ſeparates from Buxton-Water.

The permanent Vapour muſt be ſuppoſed meaſured when the Temperature of the Air was about 40° or 50°; and the Preſſure of the Atmoſphere denoted by 29 $\frac{1}{2}$ Inches of the Quickſilver-Barometer.

In this Experiment it appears that Water is ſaturated by about $\frac{1}{46}$ or $\frac{1}{48}$ of its Bulk of Air of the Atmoſphere, by about $\frac{1}{53}$, to about $\frac{1}{55}$ of its Bulk of the permanent Vapour that ſeparates from Buxton-Water, and by $\frac{1}{48}$ to about $\frac{1}{63}$ of its Bulk of Air *altered* by Expoſure to Iron mixed with Sulphur: alſo by about $\frac{1}{45}$ of its Bulk of a Mixture of equal Parts of Air and of the permanent Vapour that ſeparates ſpontaneouſly from Buxton-Water.

Hence we ſhould believe that there is no great Difference in the Solubility of common Air, this permanent Vapour of Buxton-Water, and Air ſaturated with Phlogiſton.

In this Experiment it is of practical Importance to obſerve, that a greater Quantity of a Mixture of the permanent Vapour that ſeparates from Buxton-Water and Air was united with Water than is found naturally combined in the tepid

Springs

Springs of Buxton, for we found Water combined with $\frac{1}{45}$ of its Bulk of this Mixture; whereas the Springs of Buxton only afforded $\frac{1}{64}$ of their Bulk of a Mixture of these two Substances.

But as little or no Agitation or extraordinary Pressure was employed in this Experiment to unite permanent Vapour with Water it is probable that besides the Quantity of it chymically combined in this Experiment, a further Quantity may be diffused through, or suspended in, the Water.

As the Quantity of permanent Vapour dissolved by Water is greatest (*f*) when the Water is pure, and under certain Degrees of Heat, Pressure, and Agitation; when it is wished to exhibit as a Medicine the permanent Vapour of Buxton-Water, and it is required to have as large a Quantity of it as possible in the Water, these Circumstances must accompany the Combination; and we can, therefore, compose by Art, a Water more copiously impregnated with this permanent Vapour than is furnished by Nature; provided however that the Whole of the permanent Vapours contained in Buxton-Water be separable by the Heat employed, p. 233, Vol. I.

It is very probable, however, that Buxton-Water contains a greater Quantity of the permanent Vapours than can be separated by the Heat em-

(*f*) P. 242, Vol. I. this Work.

ployed,

ployed, (p. 232, Vol. I.) becauſe it has been ſhewn by Mr. De Luc that Water retains a Quantity of Air that cannot be detached by a boiling Heat long applied, but which was yielded by long-continued Agitation in Vacuo (*g*). And therefore the Effects of Buxton-Water upon the human Body produced by the permanent Vapour that riſes ſpontaneouſly are not to be conſidered, perhaps, as the mere Effects of the Quantity obtained by Expoſure to Heat, but alſo of what remains ſo united with Water as not to be extricated by this Means.

There is a great Variety in the Reſult of the Experiments to ſhew the Quantity of Air capable of being combined with Water. Some Experimenters have found that Water combined with $\frac{1}{28}$ of its Volume of Air, others only with $\frac{1}{70}$ of its Bulk of this permanent Vapour. It is therefore very probable there may be alſo a conſiderable Difference in the Quantity of this permanent Vapour of Buxton-Water capable of being united with Water upon different Occaſions.

The following Experiment was made to learn whether this permanent Vapour of Buxton-Water can be changed wholly or partially to the State of Air by Decompoſition or Combination, in Conſequence of Agitation in Water, or by mere Expoſure to Water.

(*g*) — Treatiſe on Gaſes, p. 76.

Exper.

Exper. XLVII. I have not found that this permanent Vapour is at all *altered* by being in Contact with one hundred Times its Bulk of boiled pure Snow-Water, or Lime-Water, from the Space of one Week to six Months; or that it suffers the smallest Alteration in Quality by being repeatedly transferred through this pure boiled Snow-Water and Lime-Water for several Minutes.

About two Ounce Measures of this permanent Vapour of Buxton-Water in a ten Ounce Jar of Pump-Water, and this Quantity of Air wholly *changed* by uniting with Phlogiston, or by other Means, during its Exposure to the putrefactive Fermentation, in a like Jar of Pump-Water, were agitated in a small Tub of the same Pump-Water for two or three Hours in a Room of a temperate Heat. After this Time the Bulk of the included permanent Vapours was evidently enlarged although it was of the same Heat, and subject to the same Pressure as before this Agitation in Water. Being now submitted to the Test of nitrous Gas I found one equal Measure of the former permanent Vapour and nitrous Gas were reduced after Mixture to one Measure and eleven-eighteenths; and the other permanent Vapour mixt in the same Quantity with nitrous Gas was diminished in Bulk to one Measure and thirteen-eighteenths. Before this Exposure to Water these Vapours were found not to suffer any Diminution with nitrous Gas that could be ascribed to Combination.

This

This Increaſe of Bulk after Agitation was referred entirely to the Addition of Air extricated from the Pump-Water during ſhaking; but as the Diminution of its Volume on Mixture with nitrous Gas appeared greater than might be expected to happen from the additional Quantity of Air, I conjectured that the Air was produced partly by being extricated from the Pump-Water, and partly by a partial Change of the included permanent Vapours to the State of Air, provided no Part of the included permanent Vapours was abſorbed by the Water.

This Experiment was made more accurately by uſing Water that had been long *boiled*, and expoſed as ſhort a Time as poſſible to the Atmoſphere after boiling.

Inſtead of an Increaſe of Bulk as before, the permanent Vapours by Agitation for two Hours and a half were *diminiſhed* conſiderably; and the Dimenſions of a Mixture of equal Bulks of nitrous Gas and the above permanent Vapours were, after Mixture, reduced to one Meaſure and about one-fourth.

This Experiment was repeated a ſecond Time with boiled Water in which the above permanent Vapour of Buxton-Water was diminiſhed by Agitation $\frac{1}{40}$ of its Bulk: and the Bulk of a Mixture of two Meaſures of this Subſtance and one Meaſure of nitrous Gas was, after Mixture, two Meaſures

and

and about one-ſixth to two Meaſures and one-ninth; as appeared on ſeveral Trials.

The remaining permanent Vapour of Buxton-Water was then agitated further until one half of its Bulk was abſorbed, but I did not find that it ſaturated the Phlogiſton of a larger Quantity of nitrous Gas than before.

The permanent Vapour that ſeparates itſelf from Buxton-Water was upon another Occaſion, by Agitation in a very large Quantity of boiled Water reduced to about the State of a Mixture of equal Parts of Air and this permanent Vapour of Buxton-Water (*b*); but it did not appear however long the Agitation was continued after this Time, that it was capable of being made to approach nearer to the State of atmoſpheric Air.

Hence, at firſt, it appeared to me, that theſe permanent Vapours were partially changed to the State of Air by Agitation in a large Quantity of boiled Water that communicated with the Atmoſphere.

This Concluſion, however, on further Conſideration, did not appear warrantable, becauſe it was conceived that the Agitation in Water communicating with the Atmoſphere might inviſibly, or unobſervedly both expel the included permanent Vapour into the open Air, as well as at the ſame Time introduce Air from the Atmoſphere:

(*b*) Page 96, this Vol.

and

and I have in a former Part of this Work, (p. 90, and ſeq. Vol. I.) endeavoured to ſhew that Air injured by Combination with Phlogiſton, or by other Means, has not been proved to be changed by Means of Agitation in Water wholly or partially to the State of Air, p. 93, Vol. I. Note (*f*). I therefore repeated this Experiment in the following Manner.

An Ounce Meaſure of the permanent Vapour that ſeparates from Buxton-Water was agitated in ten Ounces of boiled Water, which Water did not communicate with the Atmoſphere, the Bottle containing it being corked. By this Means the Bulk of this permanent Vapour was diminiſhed, but not at all changed to the State of Air according to the Teſt of nitrous Gas. This was the Reſult of ſeveral Trials.

I repeated the Experiment of agitating this permanent Vapour of Buxton-Water in Water, communicating with the Atmoſphere, mixt with common Air.

A Mixture conſiſting of ſix Drachms Meaſure of common Air, and as much of this permanent Vapour of Buxton-Water, ſome of which Mixture with an equal Bulk of nitrous Gas was reduced, after Mixture, to one Meaſure and five-ninths, was ſhook with ten Ounces of boiled Water in a Tub of the ſame until half of this Mixture was united with the Water. The Reſiduum, to the Teſt of nitrous Gas, was not much altered by this Agitation, as appeared by the Dimen-

ſions

ſions of this Subſtance after Mixture with this Teſt.

It appears that in the laſt Trial the common Air having a ſtronger Attraction for Water it combined in a greater Proportion with the Water than the permanent Vapour of Buxton-Water; and although common Air was not only expelled from, but introduced into, the Veſſel agitated, we can underſtand how it happened that after half the Bulk of permanent Vapour was abſorbed the Reſiduum did not appear to contain more common Air than before.

The laſt Experiment which I ſhall relate is the following one,—it was made to learn whether the permanent Vapour of Buxton-Water that ariſes ſpontaneouſly *combines* with, or only *diffuſes* through Air.

Exper. XLVIII. A Pint and a Quarter Meaſure of the permanent Vapour that ſeparates ſpontaneouſly from Buxton-Water was added to as much Air in a large Florentine Flaſk inverted in Water. This Mixture obſerved in a good Light was perfectly *tranſparent*; neither produced *Heat* nor *Cold* to the Senſe of Touch; nor Alteration in the Sum of the *Bulk* of the two Subſtances ſeparately, after being mixed together: therefore there were no Signs of chymical Combination.

The Diminution ariſing on many Trials from Mixtures of equal Portions of this Mixture of nitrous Gas was the ſame, or nearly ſo, and was

the ſame, or nearly the ſame, as when half a Meaſure of Air was added to one Meaſure of nitrous Gas and half a Meaſure of this permanent Vapour of Buxton-Water. And Animals lived nearly the ſame Time in equal Portions of this Mixture, therefore it was probable theſe two permanent Vapours were *diffuſed* through each other but not *chymically united.*

Summary View of the Reſult of PART III. *of this Work.*

I have now related the Experiments and Obſervations to diſcover the Properties of the permanent Vapour that ſeparates itſelf in the Form of Bubbles from the Bath at Buxton; by which we are informed,—that by *Preſſure* accompanied with Degrees of Heat and Cold far exceeding thoſe of the Atmoſphere, it is readily contracted in its Dimenſions, and upon removing that Preſſure it returns to preciſely the ſame Volume as before; —that by *Heat* it is readily expanded and by Cold ſpeedily contracted; and that it is, perhaps, ſubject to nearly the ſame Law with Regard to Expanſion as Air;—that its *ſpecific Gravity* is the ſame or rather leſs than that of common Air, and of Air *united* with Phlogiſton, or Air *altered* by the putrefactive Fermentation, by Reſpiration, and by Expoſure to a Mixture of Iron and Sulphur;—that it is *tranſparent* and *colourleſs* in any Bulk that can be

be conveniently viewed together;—that it has *no Taste* or *Smell*; is *ſonorous*; when in Motion may be *felt*, as then it is found to excite the ſame Senſation as the Motion of the Air called Wind; and it poſſeſſes the Property of Viſcidity.

This permanent Vapour has been ſhown in the foregoing Experiments to be wholly unfit for the *Reſpiration* of Quadrupeds, Birds, Fiſhes, amphibious Animals, and Inſects; and that Animals die therein for the ſame Reaſon, and in probably the ſame Time as in the Air-Pump: but it was not found to be poiſonous to Quadrupeds when taken into the Stomach.—It has been ſhewn that *Fiſhes* are killed in the tepid Water of Buxton by the *Heat* of the Water, and not by the *Impregnation* of the permanent Vapour that ſeparates ſpontaneouſly;—that the *Light* and *Flame* which accompany Inflammation are extinguiſhed by being immerſed in this permanent Vapour;—that Phoſphorus, Water, and *any* permanent Vapour produce an Appearance upon Motion in the Dark juſtly reſembling the *phoſphoreal Light of the Sea* in the Night-Time;—that Phoſphorus by long Agitation ceaſes to ſhine in permanent Vapour; but the Phoſphorus itſelf, or its Phlogiſton combines therewith, and forms *a Vapour which emits a Flame upon Expoſure to atmoſpheric Air*;—*that inflammable Subſtances which burn, or are decompoſed by Air without Light or Flame*, as nitrous Gas, do not burn, or are not decompoſed by the

 perma-

permanent Vapour that arises from Buxton-Water;—that the permanent Vapour extricated by the Heat of boiling Water from Buxton-Water, consists, upon an Average, of about *equal Parts* of that permanent Vapour which arises spontaneously from this tepid Spring, and Air;—and that under a mean Pressure, and in a temperate Heat of the Atmosphere, the *Bulk* of these two permanent Vapours to the Water is as 1 to 64;—that *Seeds* do not grow in, but the living Principle is not destroyed by the permanent Vapour that separates itself spontaneously from Buxton-Water, inflammable Air, and Air totally *altered* by Respiration, Putrefaction, and Air united with Phlogiston by Inflammation;—that *Plants* grow, and frequently in a somewhat luxuriant Manner, in the permanent Vapour that arises from Buxton-Water, in inflammable Air, and in Air totally *altered* or saturated with Phlogiston by various Processes, for a short Time, then die, sometimes suddenly, in general, gradually;—that *Vegetation* very probably never changes the permanent Vapour that arises from Buxton-Water, and Air totally *altered* or saturated with Phlogiston, partially or wholly to the State of atmospheric Air; —but that the Air found sometimes in Receivers of permanent Vapours different from Air, in which Plants have lived, is most probably excreted by the Plants, and added to the included permanent Vapour;—that the mucilaginous and putrefactive

Fermen-

Fermentations take Place in the permanent Vapour that ſeparates from Buxton-Water, and in Air *altered* entirely by various Proceſſes;—that an Animal ſuffocated by this permanent Vapour of Buxton-Water does not *putrefy* ſooner than an Animal killed by ſome mechanical Injury of a vital Part;—that Solutions of metallic Salts mixed with a large Quantity of Water decompoſe in this permanent Vapour, and in Air totally *altered* by Reſpiration, Putrefaction, and phlogiſtic Proceſſes, and in *Air*, as well as when excluded from Air or any other permanent Vapour;—that to the Teſt of Infuſion of Archill and Juice of Violet Flowers, the permanent Vapour ariſing from Buxton-Water is neither an Acid nor Alkali, nor to the Teſt of *Saccharum Saturni*, contains or ſeparates Phlogiſton;—that various Acids, Alkalies in a mild and cauſtic State, Solution of neutral, earthy, and metallic Salts, Alcohol, Oils, and Solution of Soap, have no Effect in decompoſing or altering this permanent Vapour of Buxton-Water, but abſorb a ſmall Quantity of it;—that common *Spring-Water* and *Lime-Water* ſaturated with common Air, or as in their natural State, do not unite with this permanent Vapour; —that *common Spring-Water*, deprived of its natural Proportion of Air, abſorbs about $\frac{1}{46}$ or $\frac{1}{48}$ of its Bulk of Air of the Atmoſphere, $\frac{1}{53}$ or $\frac{1}{55}$ of its Bulk of the permanent Vapour that ariſes from Buxton-Water, and $\frac{1}{48}$ to $\frac{1}{63}$ of its Bulk of

 Air

Air ſaturated with Phlogiſton, or altered by Expoſure to a Mixture of Iron and Sulphur; alſo $\frac{1}{45}$ of its Bulk of a Mixture of equal Parts of permanent Vapour of Buxton-Water and Air;—that this permanent Vapour is not at all *altered* by being a long Time in Contact with Water or Lime-Water;—that by Agitation in a large Quantity of boiled Water expoſed to the Atmoſphere, this permanent Vapour, as well as Air ſaturated with Phlogiſton, or *altered* by various Proceſſes, mixes with the external Air; which Addition or Mixture has been miſtaken for a Change of theſe Subſtances into Air; but that theſe Subſtances are not altered by Agitation in Veſſels wherein the Water is excluded from the Atmoſphere, nor, perhaps, when mixed with a pretty large Proportion of common Air, and in Veſſels of Water communicating with the Atmoſphere;—and laſtly, that this permanent Vapour does not *combine* with, but is *diffuſed* through, atmoſpheric Air.

I have now related all the chemical Properties of, and all the Subſtances contained in, the tepid Springs of Buxton, which are perhaps diſcoverable by the beſt Means yet known of aſſaying Spring-Waters; but it muſt be remembered, that as the Knowledge of the natural Hiſtory of this Subject advances, in future other Properties and Subſtances may be detected. On this Account, the Inſtruction hereby received muſt only be employed to direct us in the Application of this

Subſtance,

Subſtance, ſo long as Experience of its Effects in Diſeaſes is wanting for our Guide, and for the Interpretation of natural Phenomena: and we are not to reject the Uſe of it in any Caſe, although the Facts alledged of its ſalutary Influence do not agree with Principles which have for their Foundation the chymical Hiſtory of this tepid Water, or are inexplicable upon any Hypotheſis that may have been adopted.

I next attempted to account for the diſtinguiſhing Properties of Buxton-Water, or for thoſe Qualities in which its peculiar medicinal Powers reſide.

SECTION I.

Concerning the Occaſion of the peculiar chymical Properties of Buxton tepid Springs.

A Contemplation of the preceding Hiſtory inſtructs us, that the diſtinguiſhing, and medicinal Properties of Buxton Water, are

1. *A ſmaller Quantity of ſolid Subſtances than is uſually found diſſolved in Springs.*

2. *A Degree of Heat much exceeding that of ordinary Springs;—being about* 82° *inſtead of* 48° *or* 50°, *the general Temperature of Spring-Waters in England.*

3. *The Impregnation with a peculiar permanent Vapour which is both diſſolved and ſuſpended therein; and which ſeparates itſelf ſpontaneouſly as ſoon*

as it breaks out upon the Surface of the Earth—when the Preſſure of the Earth is removed.

From the Hiſtory of the internal Structure of the Earth of the Peake, and of the Subſtances contained therein (*i*) we ſhould have been able to account for a ſtronger *Impregnation,* and for a greater Number of Subſtances being contained in theſe tepid Springs, or for the uſual Quantity of Subſtances diſſolved in them; but why they ſhould contain the ordinary Kinds of Things, viz. *Sea-Salt, vitriolic Selenites,* and *calcareous Earth* in Quantity ſo much ſmaller than in general, is not obvious from the natural Hiſtory of the Part of the Earth from which they ariſe.

The efficient Cauſe of the mean Heat of the Earth and of the ordinary Temperature of cold Springs in England being very generally from 48° to 50° has never been attempted to be aſſigned; but that of warm Springs has frequently been given, namely, either the *Decompoſition of Iron Pyrites,* or *ſubterranean Fire.*

Concerning the Origin and Compoſition of the peculiar permanent Vapour which extricates itſelf ſpontaneouſly from Buxton-Water, and which has ſcarcely yet been generally known to exiſt, not ſo much as a Conjecture, that I know of, has been offered. If however the Reader conſiders the Arguments to render it extremely probable, that the permanent Vapour known by the Name

(*i*) Vol. I. p. 43 to 67; and p. 139 to 142.

of

of the Choke-Damp, which is abundantly and very generally contained in the Cavities of the interior Parts of the Cruſt of the Earth, is *the Compound of Air and Phlogiſton*, and not, as has been univerſally ſuppoſed, Gas (*k*); and has perceived the Reſemblance in many Properties between this permanent Vapour of Buxton-Water and *the Compound of Air and Phlogiſton*, he will conclude, *that this permanent Vapour of Buxton-Water and the Choke-Damp are, very probably, the ſame Thing*. But the Origin of the Choke-Damp has been ſhewn on very probable Grounds to be ſubterraneous Fires (*l*); which like all other Fires neceſſarily compoſe *the Compound of Air and Phlogiſton* (*m*).

This permanent Vapour that ariſes from Buxton-Water appears to be not only, like the Choke-Damp, the eſſential Effect of Inflammation in the internal Parts of the Earth, but probably of Inflammation actually ſubſiſting there; becauſe it hath already been rendered probable that it is in the ſame Form as in the Buxton tepid Waters in the warm Springs of Bath (*n*), and had Attention been beſtowed would probably have been oftentimes obſerved, if not always, in other *Thermæ*: but it has never been ſeen in any of the cold

(*k*) Vol. I. p. 112 to 117.
(*l*) Ibid. p. 113.
(*m*) Ibid. p. 114, 115.
(*n*) P. 11 and 12. this Vol.

Springs, which are daily Subjects of univerſal and the moſt familiar Obſervation.

This Theory of the Origin and Formation of this permanent Vapour of Buxton-Water is grounded on the Suppoſition that ſubterraneous Inflammation is the ſame Thing as Inflammation which is produced in the Atmoſphere, that is, the uniting of Air and Phlogiſton.

I am therefore led next, to conſider the Nature of the aſſigned efficient Cauſes of Springs much exceeding their ordinary Temperature—48° or 50° —in the Climate of England.

I. *The Decompoſition, generally, but moſt improperly called the Fermentation, of Iron Pyrites.*

This Subſtance is compoſed of Sulphur and Iron chymically united. It is contained in Veins, and is found in Maſſes intermixed with Strata, Beds, Veins, and Dykes, &c. of Earths, and Ores. When it is *moiſtened* and expoſed to the *Atmoſphere* it is decompoſed: for the Principle of Inflammability united to the vitriolic Acid, forming Sulphur, combines with the Air of the Atmoſphere and produces *Heat*, accompanied in certain Circumſtances with *Flame*, and at the ſame Time the vitriolic Acid of the Sulphur combines with the Calx of Iron therewith forming green Vitriol, or Vitriol of Iron;—during this Union of

of vitriolic Acid and Calx of Iron *Heat* alſo is occaſioned.

Beds of combuſtible Matter, as Coal and aluminous Shale, containing Iron Pyrites in Maſſes; or theſe inflammable Matters in Heaps expoſed to the Air of the Atmoſphere have on many Occaſions been ſet on Fire by the Decompoſition ot the Iron Pyrites intermixed with them. The Heat produced by a Mixture of Iron-Filings and Sulphur with a certain Proportion of Water and Expoſure to the open Air, has been long very generally known; and, when among many others, Lemery, Shaw, Buffon, and very lately the preſent learned Biſhop of Llandaff, ſhewed, that if this Mixture be interred a few Feet in the Ground, in a ſhort Time the ſuperincumbent Earth is elevated, dried, cracked, and heated;—then burſt, Smoke emitted, followed by an Eruption of Fire with Flame, and an Appearance of much Light; in ſhort, that all the Phenomena in Miniature of a Volcano were produced, the efficient Cauſe of ſubterraneous Fires, Earthquakes, and Volcanos was ſuppoſed to be demonſtrated.

We have the moſt probable Reaſons for believing that ſubterraneous Fires, or at leaſt extraordinary ſubterraneous Heat, continue for Ages under ſuch Circumſtances as to have no Communication with the Atmoſphere; and ſtill more probable Grounds for believing that there are no Reſervoirs or Cavities in the internal Parts of the

 Globe

Globe containing Air to support Inflammation, or in Quantity sufficient to produce this Effect for any considerable Time; consequently, when Iron Pyrites is decomposed in the Bowels of the Earth there is no Heat produced by the Combination of Air with the Phlogiston separated from the the Sulphur, but *Heat by the Union of the vitriolic Acid of the Sulphur and Calx of Iron only* (*o*). Pyrites decomposed under these Circumstances may heat, and even melt combustible Matter, as Shale and Coal, but cannot set them on Fire as in the Instance above-mentioned.

Subterraneous Fires cannot therefore be occasioned by this, or any other Substance without Air; but as it is liable to decompose independently

(*o*) The learned Author of the *Conjectures concerning Earthquakes*, &c. 1760, p. 13. Sect. II. seems to be of Opinion, that subterraneous Fires may subsist without Air. The Paragraph in which this Opinion is delivered, and the Instance in Support of it is as follows: "How well soever these Facts may agree with the Supposition before laid down, that subterraneous Fires are the Cause of Earthquakes, one Doubt, however, may perhaps remain; viz. How is it possible that Fires should subsist which have no Communication with the outward Air? In answer to which, I might alledge the Example of green Plants, which take Fire by Fermentation when laid together in Heaps, where the Admission of the outward Air is so far from being necessary, that it will effectually prevent their doing so." I confess, I have not been able to perceive, that this Example is a Proof that Substances may burn without Air. This Instance, I conceive, only proves,

dently of this permanent Vapour (*p*) ſubterraneous Heat may by this Means be occaſioned. It is, however, extremely doubtful, indeed it is improbable, from the Quantity and Situation of Pyrites under Ground, that this Heat ſhould be ſo great as to melt Strata of Earth of many Miles in Extent, and perhaps many hundred Yards in Thickneſs; and to expand, elevate, and burſt the ſuperincumbent Beds of ſtony Matter of many Miles in Thickneſs: and, by thus fracturing the incumbent Earth to open a Communication between the Atmoſphere, and the Pyrites partially decompoſed—in which Caſe we naturally conceive a Concuſſion of the Earth to happen, an Inflammation inſtantly to take Place, Smoke, Light, and Flames to burſt through the Surface of the Earth in Abundance, accompanied with, or ſucceeded by the Irruption of a Flood of li-

proves, that dead Plants do not take Fire during Fermentation, unleſs under certain Circumſtances, viz. a certain Quantity of them heaped together, a certain Quantity of Moiſture, and ſufficient Air applied to the external Surface of the Maſs—which laſt Circumſtance is always neceſſary to the Firing of any inflammable Subſtance—but when Air is admitted to rob the Plants of their Moiſture, no Inflammation happens.

(*p*) Inſtances may be found (Dr. Prieſtley's Exper. and Obſ.) of the Decompoſition of a Mixture of Iron and Sulphur expoſed to nitrous Gas, Oil of Metals, and Gas; alſo in exhauſted Receivers, and while immerſed in Quickſilver. Theſe Facts prove that Air is not eſſentially neceſſary to the Decompoſition of theſe Subſtances.

quid

quid Fire that may inundate the Surface of the Earth many ſquare Miles in Extent. Therefore natural Volcanos are in all Probability produced by a different efficient Cauſe from the artificial ones occaſioned by burying a Mixture of Iron and Sulphur a few Feet or Yards below the Surface of the Earth; and conſequently alſo that the Decompoſition of Iron Pyrites is at any Rate a very improbable occaſional Cauſe of the tepid, warm, or hot Temperature of Springs;—above all of thoſe Springs which exceed the common Standard of Heat of Spring-Water, for many hundreds or thouſands of Years; inſtead of the ordinary Degree of Heat of them in England, 48° or 50°, when they excite the Senſation of Cold.

Moreover, the Decompoſition of Pyrites *without Air* cannot, with any Degree of Probability, be aſſigned as the Occaſion of thoſe Earthquakes which are produced by the elaſtic Power of Water in a State of Vapour; becauſe we have no Grounds for believing that this mineral Subſtance is contained in *Quantity* ſufficient to cauſe Heat, without the Application of Air, capable of converting Water into Vapour, and of expanding this Vapour in ſuch a Manner as to ſhake a conſiderable Part of the whole Globe.

II. *Subterraneous Fires.*

It is proper to obſerve, although I do not think it neceſſary to ſtate the Proofs, that Heat hath ſubſiſted,

ſubſiſted, or doth exiſt at a pretty conſiderable Depth below the Surface of the terreſtrial Portion of the Globe, very generally throughout the whole exterior Part of the Earth, in a Degree ſufficient to melt entire, or a great Part of, Strata of ſolid Matters, or to rupture the ſuperincumbent Beds.

The only adequate efficient Cauſe of this ſubterraneous Heat beſides that juſt mentioned, and ſhewn to be inſufficient, that has been aſſigned, is *Inflammation*; but as Inflammation is the Combination between Air and Phlogiſton, this Phenomenon has been hitherto either conſidered as inexplicable, or the Explanation given of it has been upon erroneous Grounds.

Indeed human Induſtry has been ſo little employed in explaining the Structure of the interior Parts of the Earth, and the Nature of the Subſtances of which it is compoſed, that we can only form Conceptions of its Materials, and the Operations therein performed by Analogy: and we reaſon from our Knowledge of what happens above the Surface of the Earth, or a little Way beneath it. It is much to be lamented that Mankind ſhould have neglected the Cultivation of ſo very uſeful, although moſt laborious and expenſive a Part of natural Hiſtory, and upon other Occaſions have employed themſelves in Works of much greater Labour and Expence that were of no Benefit to future Ages. Si les Rois d'Egypte au lieu d'avoir fait des Pyramides, & élevé d'auſſi faſtueux Monumens

numens de leurs Richeſſes & de leur Vanité, euſſent fait la même dépenſe pour ſonder la Terre, & y faire une profonde Excavation comme d'une lieue de profondeur, on auroit peut-être trouvé des Matières qui auroient dedommagé de la Peine, & de la dépenſe, ou tout au Moins on auroit des Connoiſſances qu'on n'a pas ſur les Matières dont le Globe eſt compoſé a' l'intérieur, ce qui ſeroit peut-être fort utile (*p*).

In this State of Ignorance we can only propoſe that Hypotheſis which will beſt explain the Phenomena of ſubterraneous Inflammation.

The Deflagration of Nitre, and the Inflammation of Subſtances containing Nitre, when heated to a certain Degree, independent of the external Application of Air, as in exhauſted Receivers, being effected by a very pure Air, or a Sort of Air that ſerves in a more eminent Degree for Inflammation and Reſpiration than atmoſpheric Air, abundantly detached from itſelf (*q*), afforded an Explanation of ſubterranean Inflammation; and

(*p*) *Buffon*—Théorie de la Terre, Article IX.

(*q*) Gunpowder may be fired in Vacuo, and Air is left after the Exploſion, and alſo in Air ſaturated with Phlogiſton.

Dr. *Rutherford* (Diſſertatio Inauguralis de Aëre Mephitico, 1772) found, that when inflammable Subſtances, of which Nitre was a Part of their Compoſition, burnt in Receivers of Air, there was an Augmentation of the Bulk of the permanent Vapour in the Receiver after the Inflammation, in Conſequence of the Air detached from the Nitre.

the Separation of this pure Air by mere Expoſure of various foſſil Subſtances to Heat (r), alſo contributes further to enable us to account for this Phenomenon.

If then we ſuppoſe that there are beneath the Surface of the terreſtrial Part of the Globe entire Beds of combuſtible Matter, or Beds conſiſting, principally, of inflammable Subſtances, of ſuch a Nature as to burn when heated to a Degree ſufficient to ſeparate pure Air from themſelves, or perhaps from Subſtances in Contact, and intermixed with them; in Conſequence of this Decompoſition, by which pure Air is extricated, we can underſtand without Difficulty how Fires may be produced in the interior Part of the Earth where no Air is contained in a ſeparate State, but combined with the combuſtible Subſtances themſelves, or the Matters in Contact with them.

I was pleaſed to find this Explanation of ſubterraneous Fires had occurred, ſeemingly, from the ſame Conſiderations to Mr. *Cavallo* in his Work on *Air and other permanently elaſtic Fluids*, p. 573. " The Exiſtence of ſubterranean Fires may be explained in the preſent State of Knowledge relating to dephlogiſticated Air; it being detached from ſeveral burning Bodies within the Bowels of the Earth by Means of Heat. It will ſerve to account for thoſe very Fires which are the inſtrumental Means of its Production, from

(r) Dr. *Prieſtley*'s Exper. and Obſerv.

the

the divers Minerals which contain this pure reſpirable Fluid."

Here then we can perceive an adequate efficient Cauſe of tepid, or warm Springs, viz. ſubterraneous Fires; and as a probable Proof of this Operation of Nature being the Occaſion of the ſuperior Heat of Springs, I obſerve, that ſuch Springs eſpecially abound in Regions where ſubterraneous Fires actually ſubſiſt, as in Italy. Moreover, as theſe Fires have happened, or may now ſubſiſt in Regions where the Evidence of them is not very obvious at preſent, excepting that there are a few warm or tepid Springs; and laſtly, as no other probable Occaſion can be aſſigned but ſubterraneous Inflammation, we venture to pronounce this Operation to be the only probable efficient Cauſe of tepid, warm, and hot Springs.

Therefore the probable Occaſion of certain Springs at Buxton being tepid or 82°, *inſtead of* 48° *or* 50°, *is ſubterraneous Heat produced by Inflammation.*

Moreover we have very probable, but perhaps not deciſive Facts, that demonſtrate, if not the Subſiſtence of ſubterraneous Inflammation, certainly that it hath exiſted (*s*), and moſt probably, that the Heat thereby produced is not yet extinguiſhed in the interior Part of the Earth from whence theſe tepid Springs ariſe.

That ſubterraneous Fires were at leaſt one of the occaſional Cauſes of the extraordinary Heat

(*s*) P. 45, 59. to 67. Vol. I.

of

of Springs has been frequently mentioned, although the manner in which that Inflammation is occasioned has not been underſtood.

Having ſubmitted to the Reader an Hypotheſis that may ſerve to convey an Idea of the efficient Cauſe of this natural Phenomenon—the ſuperior Heat of Springs—till an efficient Cauſe ſhall be demonſtrated by Facts, I beg leave to propoſe my Conjectures concerning the Means by which theſe, and other tepid, as well as warm and hot Waters, preſerve an *uniform Temperature, and flow in the ſame Quantity* for many hundred, or many thouſand Years.

As the following is the only and firſt Attempt hitherto made, as far as I know, to interpret theſe curious and intereſting Particulars, I hope it will not be ſcrutinized with Rigour; and although the Hypotheſis to be propoſed be not found ſatisfactory, it may be uſeful by being the Means of exciting in the Minds of others an Explanation upon a better Foundation.

When a Spring-Water flows through its ſubterraneous Paſſages within the Earth ſo as to be out of the Reach of the Influence of the Temperature of the Atmoſphere, of the Heat of the Surface of the Earth produced by the Rays of the Sun, Fermentation, Inflammation, and animal Life, it probably aſſumes in England very generally a Temperature expreſſed by 48° or 50° of

 Fahren-

Fahrenheit's Thermometer, unless it be exposed to local subterraneous Heat.

The principal, or only local Occasion of subterraneous Heat, I have assigned to be that produced by Inflammation (*t*). When a Spring flows upon, or through a Mass of inflamed Matter, or when the Inflammation is extinguished but the Matter or Earth remains heated, by being contiguous thereto, its Heat is variously increased, and receives frequently such an Increase of Heat that the whole of its additional Heat is not imparted or diffused in its Passage to the Surface of the Earth; and therefore it there appears as a tepid, warm, or hot Spring, according to the Quantity of Heat received and afterwards communicated.

Now in which ever of the above States the Mass be in from which the Spring derives its extraordinary Heat, we should not expect, from the Nature of Inflammation and the Laws of Heat, that precisely the same Augmentation of Heat would be communicated to the Water flowing through or near it; because while a given Quantity of any inflammable Substance is burning the Quantity of Heat thereby produced will certainly be liable in equal Times to vary for obvious Reasons: And when a Quantity of any Substance whatever is heated, so that its Temperature exceeds that of

(*t*) P. 176, this Vol.

the

the ſurrounding Matter, it communicates Heat until it be of the ſame Temperature as the Subſtances around it: but as the tepid Waters of Buxton and ſeveral warm Springs in other Parts of the Earth have been obſerved to flow in the ſame *Quantity*, and uniformly of the ſame Degree of *Heat*, and there is a good Foundation for the Opinion that they have neither varied in their Quantity nor Temperature for many hundred or even many thouſand Years, Philoſophers have expreſſed themſelves at a Loſs even to conjecture the Occaſion of this *uniform Heat*, and have not attended that *the Uniformity in the Quantity of Water* was alſo a Peculiarity of Springs of this Nature that deſerved Conſideration.

In contemplating the Effects of Heat, among other Things, I remarked that under particular Circumſtances certain ſolid and fluid Bodies expoſed to heated Subſtances could not be made hotter than a determinate Degree, however much the heated Subſtances were increaſed in Heat; nor made cooler although the heated Subſtances were diminiſhed certain Degrees: becauſe when heated to a certain Point they were gradually diſſipated in a State of Vapour, and the Cold produced by the Evaporation ſeemed to counteract the Augmentation of Heat beyond a determined Degree, however the Subſtances by which they were heated was increaſed in Heat; and when the heated Maſs by which they were heated was cooled

ſo as not to exceed a certain Diminution of Heat, the Matters heated thereby were not diminiſhed in Heat becauſe it was ſtill ſufficient to convert them into Vapour.

This Reflection ſuggeſted that ſuppoſing Water ſhould be expoſed in the Bowels of the Earth to as great a Variety of Degrees of Heat as poſſible, but provided the leaſt of theſe Degrees ſhould be that in which this Subſtance is Vapour, when it was condenſed into the State of a Fluid it would be uniformly of the ſame Temperature; and provided there ſhould be no Variety in the Temperature of the Subſtances to which it was expoſed in its Paſſage to the Surface of the Earth, it was conceived that Spring-Water heated to an unuſual Degree might flow for Ages without the leaſt Variation in its Temperature.

It will be neceſſary, however, to relate in what Manner it was conceived Water could be heated in the internal Part of the Earth, ſo as to appear upon its Surface for Ages *uniformly* of the ſame Temperature.

In explaining this Property of tepid, and warm Water, we muſt firſt mention by what Means ſubterraneous Fires are kindled, and conſider their Progreſs after being once produced.

Although I have ſaid it is extremely improbable that the Decompoſition of Pyrites ſhould be the efficient Cauſe of ſubterraneous Fires (*u*), yet

(*u*) P. 170, this Vol.

this

this Effect will be neceſſary in order to account for the lighting of the inflammable Subſtance which is the Matter of ſubterraneous Fires (*x*).

Suppoſe a pretty large Quantity of Iron Pyrites to be in Contact, or nearly ſo, with a Bed of inflammable Matter; and in Conſequence of the oozing of a ſmall Spring of Water, occaſioned by ſome accidental Change in the Texture of the Earth, the Pyrites is rendered capable of decompoſing itſelf: during this Decompoſition ſo much Heat may be produced as to detach a ſmall Quantity of pure Air from that Part of the combuſtible Maſs which is in Contact with it;—when this happens, the Pyrites partially decompoſed now expoſed to *Air*, not only may produce *Heat by the Union of vitriolic Acid with Calx of Iron*, but a much greater Degree of *Heat*, accompanied, perhaps, with Light and Flame, is occaſioned by the *Combination of Air with the Phlogiſton of the Sulphur*. The Heat ariſing from theſe two Sets of chymical Attractions may be ſufficient to ſet on Fire the inflammable Stratum adjoining to, or in Contact with the Pyrites.

The Bed of combuſtible Matter being ſet on Fire in one Part may ſuffice for the Inflammation of the whole of it; for the ſame Reaſon that a Maſs of many Species of inflammable Bodies be-

(*x*) P. 175.

ing inflamed in one Part will continue to burn until the whole be consumed.

The inflammable Stratum as it burns, forms a large Quantity of *the Compound of Air and Phlogiston*, or at least of Air totally altered by Inflammation;—expands and, perhaps, elevates a little the Earth on all Sides of it, so as to form Cavities;—dries the Earth near it, by converting its Moisture into Vapour, or by *the Compound of Air and Phlogiston* dissolving it. By the Expansion, Drying, and Elevation of the Earth, in Contact with the burning Stratum, Fissures will be liable to be produced, through which Springs may flow upon the inflamed Stratum; the Consequence of which will be the Conversion of the *fluid* Water into Water in the Form of *Vapour.*—If a sufficient Quantity of *fluid* Water be thus suddenly let in upon the Surface of a Stratum of burning or melted Matter, *Vapour* of Water may be produced of sufficient Elasticity, and in sufficient Quantity, to overcome the Gravity and Cohesion of the Earth by which its Expansion is resisted. The Consequence of this elastic Force of Water in the State of Vapour will be, to fracture the superincumbent Beds of Matter, to elevate the Earth, and it may form a *Cavity* between the Stratum of inflammable Matter and the incumbent Earth. The Production of these Effects will be accompanied with a Concussion of the Earth, perceived at the Surface thereof, called an Earthquake.

The

The Vapour that produces these Effects may force itself into various Apertures of the Earth during the Elevation thereof, where it may be condensed into a fluid State, as well as be contained in the State of Vapour in the *Cavern* thereby produced.

After the Formation of this *Cavern* it may be conceived, that Water *oozes* through various Fissures in the Roof and Sides thereof, and falls upon the burning Stratum; and that a plentiful Stream of Water *flows* through a large Aperture in the Side of this Cavern also upon the Stratum on Fire. The fluid Water that now flows upon the burning Stratum is converted into Vapour; the Elasticity of which is not able to overcome the Cohesion and Gravity of the Earth, by which its Expansion is resisted before it forces itself into the Fissures through which Water oozes from the Roof and Sides of the Cavern; and by the Force of the Vapour from behind, the Water in these Fissures flows in a contrary Direction, or from the Cavern through subterraneous Passages to the Surface of the Earth, where there appears a warm, tepid, or hot Spring, instead of cold Water of the usual Temperature of cold Springs, and, perhaps, of the Earth, about 49°.

If we suppose the inflammable Stratum to be of a very considerable Thickness, as thirty or forty Miles, as well as of a very great Length and Breadth, as eighty or a hundred Miles: or sup-

poſe this Stratum of Matter capable of burning to be even one hundred cubic Miles—(*y*), which is leſs than one two-hundred and ſixty-thouſand million Part of the whole ſolid Contents of the Earth—and to burn with about the ſame Speed as common Pit-Coal or inflammable Shale in the Atmoſphere, we ſhould not expect it would be conſumed, after being ſet on Fire in one Part only, in leſs than the Space of a great many Years;—perhaps, it would require a hundred Years to burn the whole of ſuch a Maſs, and probably two or three Times this Space of Time for ſuch a burnt Stratum to aſſume generally the Temperature of the Earth.

But we are not obliged to ſuppoſe, that this ſubterranean inflammable Matter burns ſo rapidly as the above Subſtances; it may, for aught we know, be decompoſed much more ſlowly—as gradually as Sulphur in the Heat of the Atmoſphere,—and therefore may not be conſumed in leſs than two or three thouſand Years, or a longer Space of Time.

Moreover, this ſubterraneous combuſtible Stratum may, and probably is, after Decompoſition by Inflammation by the immenſe Heat to which it is expoſed, melted and converted into Glaſs;

(*y*) If the Diameter of the Earth is 7,970 Engliſh Miles, its Anbit 25,038 ½ Miles, and its Surface 199,556,845 Miles, its ſolid Contents are 265,078,009,108 ⅓ in Miles, and 67,424,728,425,380,374,118,400,000 in cubic Inches.

or

or at leaſt into a Subſtance that like Glaſs *communicates* Heat very ſlowly.

Alſo we ſhould imagine the heated Matter after the Inflammation of it, would *part* with its Heat very ſlowly, on Account of the contiguous Earth being alſo heated conſiderably during the Inflammation of the combuſtible Stratum.

Conſidering theſe Circumſtances, who does not ſee, how an immenſe Degree of local ſubterraneous Heat may ſubſiſt for Ages—for even fifty thouſand Years—although the Law according to which this heated Matter cools be not inveſtigated; and conſequently apprehend the Reaſon of certain Springs being of a ſuperior Degree of Heat to common Springs, for three thouſand Years or upwards, as thoſe of Bath (z); and, amidſt the Variety in the Degrees of this ſubterraneous Heat, it is always maintained ſufficiently to preſerve Water in a State of Vapour.

If a ſubterraneous Fire, or a Stratum of ſubterranean Matter left heated after it has ceaſed to burn, communicates Heat to Springs in the *Manner* above-deſcribed, and, as is juſt ſhewn, if this Heat *ſubſiſts* for a ſufficient Time, I apprehend that their *uniform Temperature* and *Quantity* for many hundreds or thouſands of Years may be accounted for in the following Manner.

The Vapour that is forced into the ſmaller Fiſſures filled with the Water which oozes through the

(z) See *Jorden*'s Diſcourſe on natural Baths, by *Guidot*, 8vo, 1673.

Roof

Roof and Sides of the Cavern is firſt converted into Steam, an intermediate State between Vapour and Fluidity; and as it proceeds ſtill further in its ſubterraneous Paſſages, it is converted into a State of Fluidity. Water then, is in Fact diſtilled in this Cavern, and condenſed in certain ſubterraneous Fiſſures.

Some Time after the Vapour is forced into theſe Fiſſures that communicate with the Cavern in which the fluid Water is changed into a State of Vapour, and afterwards is condenſed into the Form of Steam, and again into that of Fluidity, the Heat of this Water upon the Surface of the Earth may be ſuppoſed, from the Conſideration of the Changes it is liable to undergo in its Paſſage from the Cavern to the Surface of the Earth, not to be uniform. 1. Becauſe the Water raiſed in the Form of Vapour, is firſt mixed with the cold fluid Water occupying the Fiſſures in which it is condenſed. 2. After all the cold Water filling theſe ſmall Crannies is expelled by the diſtilled Water that appears in its Place, the ſubterraneous Paſſages from the Cavern to the Surface of the Earth are for a certain Time more and more heated, and the contained Water, for that Reaſon, parts with leſs and leſs of its Heat. 3. After Water has flowed for a certain Time through theſe ſubterraneous Paſſages, the Parts thereof immediately in Contact with the Water are of the ſame Temperature as the included Water, and the

Earth

Earth on all Sides receives Heat from this Water; which received Heat is perceived to a certain Diſtance from its Source, and in Conſequence thereof its Diminution at its Source may be ſenſible to the Thermometer: beyond which Diſtance, although Heat be imparted, the Addition is not perceivable; becauſe the Quantity of communicated Heat beyond a certain Diſtance, bears too ſmall a Proportion to the Maſs through which it is diffuſed, to be made appear by Inſtruments; and for the ſame Reaſon, the Diminution in the Quantity of Heat, in a given Time, received by the ſurrounding Earth beyond this Diſtance in Conſequence of Heat communicated thereto, not perceivable by the Aid of the Thermometer does not perceivably increaſe the Quantity of Heat in the Source, or in the Earth within that Diſtance, by the Diſpoſition of the ſurrounding Earth to receive Heat being diminiſhed. If we next add, that the Diſpoſition of the Earth, ſurrounding the heated Water, to receive Heat is uniformly the ſame, becauſe the ſubterraneous Region is here conceived to be of the ſame Temperature at all Times, being out of the Reach of the Influence of any efficient Cauſes of Heat upon, or above, the Surface of the Earth, for any Thing we can diſcover to the contrary, Water muſt flow from the ſubterraneous Cavern above-deſcribed to the Surface of the Earth, uniformly of the ſame Temperature, and for many thouſand Years, provided ſufficient

Heat

Heat be maintained to convert Water into Vapour during that Time, and the other Circumſtances neceſſary be preſent.

It will very probably be aſked, in what Manner the cold Springs which occupied the Cavities now filled with the diſtilled and condenſed Water are to be diſpoſed of? It may be anſwered that they either flow in a certain Quantity, but in a much ſmaller Bulk than before, into the Paſſages filled with diſtilled Water, or they are entirely excluded from them and diverted into other Channels by the Elaſticity of the Vapour forced into theſe Cavities, reſiſting the Flow of cold Water into them, and from thence into the Cavern where Water is Vapour. For if a determined Quantity of cold Water ſhould conſtantly ooze into the Paſſages that convey the heated Water, the Effect will be an uniform Diminution of its Heat.

The Temperature of Water heated by ſubterraneous Fires, when it appears upon the Surface, will depend upon a Variety of Circumſtances.

I. *The Heat of the Vapour.*

The Heat of Water in the Form of Vapour depends upon the Degree of Preſſure to which it is expoſed.

The Heat of Water in the State of Vapour under the mean Preſſure of the Atmoſphere, or of a Preſſure equal to that of a Column of Quickſilver

 whoſe

whoſe Altitude is about 29 ½ Inches is about 212°; under a greater Preſſure its Heat is greater, and under a leſs Preſſure its Heat is leſs than 212°.

The Preſſure upon Water in the Form of Vapour in a ſubterraneous Cavern ſo much beneath the Surface of the Earth, as the above Caſe in which Water is ſuppoſed to be in the State of Vapour, far exceeding the Preſſure of a Pillar of Quickſilver of 29 ½ Inches in Altitude, its Heat muſt far exceed 212°. Indeed if the Heat of ſubterraneous Water in a State of Vapour did not far exceed the Heat of 212°, we ſhould be unable to account for the Springs of the Heat of boiling Water, ariſing after a ſubterraneous Paſſage of certainly many Miles expoſed to the ſurrounding Earth of the Heat of 48° or 50°; or, perhaps, of a leſs Heat of the Earth.

We need therefore be at no Loſs to conceive why the Springs of Buxton exceed the Temperature of the Earth through which they paſs; ſo as to be more than 30° warmer than the Earth, after being expoſed thereto during a Courſe of many Miles in Length.

II. The Temperature of a Spring heated by local ſubterraneous Heat, is various according to the *Extent of ſubterraneous Country through which it flows*, before it breaks out upon the Surface of the Earth; becauſe the Time it is expoſed to cool

is,

is, *cæt. par.* according to the Length of its Paſſage.

It is well known that *inanimate* Matter placed in a Medium colder than itſelf will communicate Heat to the environing Medium until it be of the ſame Temperature as the ſurrounding Bodies; and therefore a Spring flowing from its Source of extraordinary Heat imparts Heat throughout its whole Paſſage to the Surface of the Earth; unleſs before it arrives there its Temperature be the ſame as that of the Earth through which it paſſes. The longer a heated Body is expoſed in a Medium colder than itſelf, the more Heat it loſes until it is of the ſame Temperature as the circumambient Body; therefore the Heat of a Spring communicated by Expoſure to local ſubterraneous Heat will be, when it appears upon the Surface of the Earth, diminiſhed, *cæt. par.* in Proportion to the Tract of Country through which it has run from its Source of Heat.

We can form no Judgment, however, of the *Diſtance* of the Source of Heat of a Spring by the Temperature of the Water, becauſe we are not acquainted with its Heat in a State of Vapour, and the Law according to which Water ſubterraneouſly heated, and expoſed, parts with its Heat.

There are alſo other Circumſtances which vary the Temperature of Springs of extraordinary Heat independent of the Heat of them in a State

State of Vapour, and the Extent of the ſubterraneous Country through which they run;—ſuch as the Capacity of the Channel filled with the Water, the Nature of the Subſtances of which the Paſſage for the heated Water is compoſed, the Speed with which the Water flows, &c.

According to the foregoing Account of the uniform Temperature of Springs of extraordinary Heat (*a*) they muſt neceſſarily flow conſtantly in the ſame *Quantity*; for it is ſuppoſed, that the ſubterraneous Paſſages, leading from the Cavern in which the fluid Water is changed into a State of Vapour to the Surface of the Earth, are conſtantly filled with Water of an uniform Temperature; and if the Quantity of Water contained therein was various at different Times its Temperature muſt alſo vary (*b*).

Springs of unuſual Heat may be conceived, in order to account for their uniform Quantity, to be ſupplied, previouſly to their Converſion from Fluidity to a State of Vapour (*c*), by cold Springs in the more *interior* Parts of the Earth, that from the Situation, Connection, and Direction of the Vacuities of the Earth which they occupy are filled with fluid Water from Fiſſures filled with Water in the more exterior Parts of the Earth. Theſe interior Springs muſt from the Law of Gravitation always fill the Vacuities in which their Wa-

(*a*) P. 177 to 189, this Vol. (*b*) P. 186, 187, Ibid.
(*c*) P. 183, Ibid.

ter

ter is contained, or at leaſt ſo long as the Springs nearer the Surface of the Earth are filled, or even only in Part filled with Water: conſequently the Spring flowing into the Cavern (*d*) in which Water is brought into a State of Vapour always conveys the ſame Quantity of fluid Water to be changed into Vapour; and as uniformly the ſame Quantity of Water has been ſhewn to be condenſed, we can perceive how it happens that Springs of extraordinary Heat ſhould never vary in the *Quantity* of Water they pour out upon the Surface of the Earth; although at the ſame Time cold Springs in the ſame Region be liable to vary in the Quantity of Water that flows from them, according to the Quantity of Water that falls from the Atmoſphere.

The preceding Conjecture concerning the efficient Cauſe of the uniform Temperature of Springs of an unuſual Degree of Heat ſuggeſts an Explanation of one of the diſtinguiſhing Qualities of the tepid Waters of Buxton, which heretofore was unaccountable, viz. a much ſmaller Quantity (*e*) of the ſolid Subſtances which are uſually diſſolved in Springs—*Sea-Salt*, *vitriolic Selenites*, and *calcareous Earth*—than is found in Spring-Waters in general.

In order to explain the uniform Temperature of Spring-Waters of an unuſually great Degree

(*d*) P. 183, this Vol.

(*e*) P. 306, Vol. I.

of

of Heat, Recourſe was had to the Conjecture that fluid Water was changed into the (g) State of Vapour, and in that Form raiſed up and forced into ſubterraneous Crannies where it was again rendered fluid; that in ſhort the Springs poſſeſſed of extraordinary Heat had undergone a ſubterraneous Diſtillation, and conſequently provided they are not expoſed to foſſil Subſtances capable of Solution in Water they muſt flow to the Surface of the Earth of an extraordinary Degree of Purity. The tepid Waters of Buxton then, ſubſequently to their ſubterraneous Diſtillation have only been expoſed in a ſmall Part of their Paſſage to the Surface of the Earth, to Sea-Salt, vitriolic Selenites, and calcareous Earth; for which Reaſon they have not had the Opportunity of diſſolving ſo large a Proportion of theſe three Subſtances as is found in ordinary cold Springs, which not only contain the Quantity of theſe ſolid Matters natural to Rain or Snow-Water, but the Quantity they diſſolve after ſoaking through the Surface of the Earth into their ſubterraneous Channels.

It is poſſible that this ſubterraneous diſtilled Water may be conveyed from the Place where it is Vapour to the Surface of the Earth through Channels of ſuch a Nature as not to communicate the ſmalleſt Impregnation to the included

(g) P. 183, this Vol.

Water; and that the ſolid Subſtances found in a ſmaller Quantity by much than in common cold Springs are merely what are contained in the cold Water mixed with the diſtilled and heated Water during its Courſe to the Surface of the Earth.

It may, however, be alledged that the Waters which are diſtilled in the interior Parts of the Earth are as liable to diſſolve the above three ordinary Subſtances from the Length of their Courſe to the Surface of the Earth as at leaſt many cold Springs; and that upon other Occaſions tepid, warm, and hot Waters contain as great a Quantity, or a greater Proportion of ſolid Subſtances than cold Springs. This Obſervation however only proves that Springs that have been diſtilled in the interior Parts of the Earth are not *neceſſarily* more free from Impregnation of ſolid Matters than cold Springs, but it does not ſhew that the Explanation above given doth not apply where Springs of a greater Heat than common cold ones are unuſually pure.

The foregoing Theory of ſubterraneous Inflammation (*h*), and Conjecture concerning the Occaſion of the uniform Temperature of Waters of unuſual Degrees of Heat (*i*), explain the Manner in which Buxton tepid Waters, Bath warm Waters, and, perhaps, many other Springs of greater Degrees of Heat than ordinary Springs

(*h*) P. 174—176. this Vol. (*i*) P. 185, ibid.

become

become impregnated with the permanent Vapour (*k*) which extricates itſelf from, and is diſſolved in the tepid Springs of Buxton; and likewiſe with a Portion of Air which is found in a State of Solution in theſe Springs (*l*).

It has been ſhewn that the permanent mephitic Vapour which extricates itſelf from Buxton-Bath poſſeſſes perhaps all the Properties hitherto known of *the Compound of Air and Phlogiſton* (*m*); and that the Choke-Damp, although hitherto conſidered to be Gas, is moſt probably the ſame Subſtance as *the Compound of Air and Phlogiſton* (*n*).

The Choke-Damp has been ſhewn to be, moſt probably, produced by ſubterraneous Fires (*o*), and by Means of the above-deſcribed Manner in which Inflammation is ſupported (*p*) beneath the Surface of the Earth—in Conſequence of which ſubterraneous burning of Strata, Springs are heated to an uniform Degree for Ages (*q*)—we may without any Difficulty conceive in what Manner a Portion of Air is diſſolved in Springs heated by ſubterraneous Inflammation, and a Quantity of *the Compound of Air and Phlogiſton*, Choke-Damp, or the permanent Vapour that ſeparates from Buxton-Water, is combined therewith as well as ſuſpended

(*k*) P. 152, 153, Vol. I. and 21—27, this Vol.
(*l*) P. 238, Vol. I. (*m*) P. 16—165, this Vol.
(*n*) P. 109—118, Vol. I. (*o*) P. 113, ibid. (*p*) P. 175, ibid. 174—176, this Vol. (*q*) P. 185, ibid.

therein; thereby producing certain Appearances in Buxton-Water related in a former Part of this Work (*r*).

The burning, or heated Stratum to which the fluid Water is expoſed, whereby it is converted into Vapour muſt neceſſarily form an immenſe Quantity of *the Compound of Air and Phlogiſton*; which we conceive may be diſpoſed of by forcing itſelf into numerous Fiſſures or Cracks in the Earth communicating with this combuſtible or burnt Stratum, and which were produced by the violent Concuſſions occaſioned by Water ſuddenly poured in large Quantities upon a Maſs of liquid Fire.

Amongſt other ſurrounding Cavities, the Cavern in which fluid Water is changed into the Form of Vapour muſt be filled with this *permanent Vapour* compoſed of Phlogiſton and Air with which is, very probably, mixed a Portion of Air that may be conſidered as redundant or ſuperfluous to the Compoſition of *the Compound of Air and Phlogiſton*; and which redundant Air is indeed, generally, found in Receivers in which Subſtances have burnt out: becauſe it would ſeem as if there were few inflammable Subſtances that decompoſe in Air mixed with a large Portion of Air ſaturated with Phlogiſton.

The Compound, then, *of Air and Phlogiſton* mixed with a Portion of uncombined Air, ariſing

(*r*) P. 152, 152, Vol. I.

con-

continually through Apertures in the burning, or burnt Stratum into the Cavern where the fluid Water is changed into a State of Vapour is preſſed, as well as the Water in a State of Vapour, into the communicating Channels, and flows along with the condenſed Water. In the Courſe of the Water to the Surface of the Earth, as Water attracts *the Compound of Air and Phlogiſton*, perhaps, as ſtrongly as *Air*, it combines equally with theſe Subſtances until it has diſſolved all the Air to which it is expoſed, and about as large a Quantity of the other permanent Vapour (*s*); with which two Subſtances it is ſaturated. But there is expoſed to the Water a much larger Quantity of *the Compound of Phlogiſton and Air* than can be *combined* therewith, therefore a Quantity is *mechanically* mixed with it by Motion, and retained by Preſſure, and the Coheſion of the Water until it appears upon the Surface of the Earth; when from the Preſſure being removed and ſome other Circumſtances it eſcapes from the Water in the Form of Bubbles (*t*). Or all the *Air* ſeparated from the burning Matter is ſaturated with Phlogiſton, and the *Air* found in the tepid Water of Buxton is what is contained in the cold Water mixed with the warm Water in its Paſſage to the Surface of the Earth.

I need ſcarcely obſerve that by Preſſure a large Quantity of permanent Vapour may be retained

(*s*) P. 99, this Vol. (*t*) P. 152, 153, Vol. I.

in a ſuſpended State in a Fluid, for upon removing that Preſſure it extricates itſelf with conſiderable Force, and during its Eſcape from the Fluid occaſions Froth, Foam, and a ſparkling Appearance; of which we have a familiar Example on withdrawing a Cork from a Bottle of vinous Liquor in a State of Fermentation.

Oftentimes Fiſſures communicate from a burning Stratum to the Surface of the Earth through which this *permanent Vapour* eſcapes, and is manifeſted eſpecially in Italy by its ſedative Effects upon thoſe Animals which happen to be expoſed to its Influence. At other Times it is retained in Cavities of the Earth which do not communicate with the Surface thereof, and is only met with by Miners and Well-Diggers, by whom it is called *Choke-Damp*. If this permanent Vapour happens to ariſe through Cracks in the Earth within a Grotto or Cave upon the Surface thereof, its Effects are experienced upon all Animals included therein; a well-known Inſtance of which is the *Grotta del Cane* in Italy. If Water did not occupy the Meanders of the Earth which communicate from the Surface of it to the burning ſubterraneous or heated Stratum, and there were a Cavern in which are the Apertures through which the tepid Water of Buxton iſſues, we ſhould have a *Grotta del Cane* at Buxton as well as in Italy, and other Places.

SECTION II.

CONCLUSION *of this* WORK.

I HAVE now concluded the Experiments and Obſervations to demonſtrate a Part of the *Hiſtory of the particular Qualities of the Atmoſphere of the Peake; and that of the chymical Qualities of the tepid Waters of Buxton*; as propoſed (*u*) for the Object of this Work.

The Utility of the *firſt* of theſe Hiſtories will be found in Conſequence of its enabling Phyſicians to judge of the Effects that may be produced by the Uſe of *Buxton-Water*, as accompanied neceſſarily with the Influence of the *Atmoſphere of the Peake*;—to direct their Patients how to regulate their Conduct ſo as to have the beneficial Effects of the Atmoſphere exerted in the moſt powerful Manner;—and to enable them to diſtinguiſh the Effects of the *Climate* from thoſe of the tepid Waters of Buxton; and therefore to advance the Knowledge of the Properties of the Water in States of Diſeaſe.

The Hiſtory of the chymical Properties of the tepid Water of Buxton will it is hoped be found variouſly uſeful.

(*u*) P. 32, Vol. I.

1. As it informs us that the *peculiar Properties* of this tepid Water (*x*) are, an unusually small Quantity of solid Substances, and of the same Kind as those impregnating ordinary cold Springs, dissolved therein;—a Temperature of 81° or 82° of Fahrenheit's Thermometer;—and a permanent Vapour, probably, *the Compound of Air and Phlogiston*, mixed with a smaller Quantity than usual of *Air*.

As the Effects of the *permanent Vapour* that rises spontaneously from Buxton-Water, and of Water of this *Temperature*, on the human Body in Health and Disease, either when applied to the Surface of the whole Body, or when taken into the Stomach, are not known, the Effects of such a permanent Vapour and such a Temperature as that of this tepid Water can only be learned by an Investigation of the Effects of this Spring-Water, or of an artificial Compound resembling it—of pure Water of 82° externally and internally applied, and of the permanent Vapour that extricates itself from these Waters, or of *the Compound of Air and Phlogiston*; which is the same Thing as, or resembles in many Properties this permanent Vapour of Buxton-Water (*y*).

2. It appears from this History that there is no Ground for believing the Efficacy of this tepid Water externally applied depends upon the Substances with which it is impregnated; and there-

(*x*) P. 326, Vol. I. and 165, this Vol. (*y*) P. 16—125, this Vol.

fore

fore the ſame Effects under otherwiſe ſimilar Circumſtances of Atmoſphere, Exerciſe, Diet, &c. may be expected from pure Water of the ſame Temperature as that of this tepid Spring.

Alſo it is probable from the known Effects of Air, that the medicinal Effects of the permanent Vapour of Buxton-Water are produced by the permanent Vapour that ariſes ſpontaneouſly, and not from Air; and that in many Caſes, at leaſt, as the Efficacy of the Water depends upon this permanent Vapour, more certain and greater Effects may be produced by exhibiting a larger Quantity for a Doſe than is contained in the Quantity of Buxton-Water uſually drank, or than can be conveniently taken into the Stomach at a Time.

Although we ſhould be inclined to believe the *Air* in Buxton-Water, from the Quantity of it, as well as the ſolid Matters therein contained, from their known Effects, have no medicinal Qualities ſeparately; yet from the Effects of other Compounds, and of the Subſtances of which ſuch Compounds are compoſed, ſeparately, one ought to be cautious in pronouncing that theſe Subſtances which are non-efficient ſeparately adminiſtered are alſo inefficacious when jointly applied with other Subſtances, as in this tepid Water.

Moreover, it is a Queſtion whether the Effects of pure Water of 82°, and of the permanent Vapour that ſeparates itſelf from Buxton-Water be the

the ſame when exhibited *ſeparately*, as when *conjoined*, or as Buxton-Water; and if they be the ſame, it is a Matter of Importance to aſcertain their particular Effects, by which Means it is probable they may be adminiſtered *ſeparately* with more Efficacy than together; becauſe in many Caſes one of them is, perhaps, non-efficient.

This Queſtion is ſuggeſted by a known Fact concerning the Effects of Medicines, namely, that upon many Occaſions Subſtances adminiſtered together have different Effects from thoſe they produce ſeparately. For Inſtance, a Mixture of Ipecacuanha and Opium, or *Dover*'s *Powder*, operates as a Sudorific, but the former Subſtance given ſeparately is emetic or has no ſudorific Effect, and the latter Element induces Sleep without occaſioning, in general, a plentiful Excretion of Sweat.

3. As it is apparent that the Efficacy of Buxton-Water depends entirely, or principally, on the *Temperature* thereof, and of the permanent Vapour that ſeparates itſelf, we cannot expect the medicinal Effects to be produced when it is cooled, or when this Temperature is not preſerved; nor when it is drank after Expoſure to the Atmoſphere and has ſeparated a Portion of this permanent Vapour.

4. The chymical Hiſtory ſuggeſts a Method of drinking Buxton-Water, after being kept in Bottles any Space of Time, of the ſame Efficacy as

at

at its Source; abſtracting from the Effect of the *Accompanyments* of the drinking of this Water at its Source.

Pint Bottles ſhould be filled with the Water of the Bath at Buxton, and then being inverted in the Bath an Ounce Phial filled with the permanent Vapour that ariſes from the Bath ſhould be made to riſe within each of theſe Bottles in the Manner formerly deſcribed (z); this done, and while in the Bath, cork the inverted Bottles. Having withdrawn them from the Bath preſerve them inverted; or tie them over with a wet Bladder, and the inverted Poſition will be unneceſſary.

As the Atmoſphere is rarely the Heat of this tepid Water, when it is intended to be drank one of theſe Bottles muſt be immerſed in Water preſerved heated about 82°; and after it has ſtood in this heated Water a ſufficient Time to aſſume the Temperature of this Medium, the Cork may be drawn, and immediately after agitating it, with the Mouth ſtopt a little Way within the Neck by a long Cork, the Quantity to be uſed muſt be poured out, and drank as ſpeedily as poſſible.

The remaining Water in the Bottle ſhould be immediately poured into a Phial or Bottle which it will entirely fill; and immediately before drinking it ſhould be warmed after the ſame Manner as

(z) P. 23, this Vol.

the firſt Portion. This remaining Part it is manifeſt will be liable to contain a ſmaller Quantity of this permanent Vapour than the firſt Portion, ſo that when the whole Impregnation of this Subſtance is wiſhed for, only the Water firſt poured out ſhould be uſed.

By this Means Buxton-Water may unqueſtionably be drank, after keeping in Bottles, in as efficacious a State, independent of its *accompanying Circumſtances*, as at the Spring-Head; becauſe the Water is heated to 81° or 82°, and we may be certain it has not ſeparated any of its permanent Vapour;—on the contrary, moſt probably, a ſmall Quantity has been added by this Subſtance included within the Bottles containing the Water.

5. We are by this Hiſtory inſtructed how to compoſe a Water reſembling Buxton-Water in its *Temperature* and *Impregnation* (*a*), in the following Manner:

Diſtil a Quantity of common hard Spring-Water in a gentle Heat, in perfectly clean Glaſs-Veſſels, ſo as to have neither Smell nor Taſte; or if it ſhould acquire a Smell by Diſtillation, remove it by Expoſure to the open Air.

To thirty-two Ounce Meaſures of this diſtilled Water in a Quart Bottle, or in a large Florentine Flaſk, add about fourteen Grains of the pureſt

(*a*) P. 321 to 327, Vol. I. and 98, 99, this Vol.

Chalk in fine Powder; and four Grains of vitriolic Selenites, composed by saturating Quick-lime, precipitated from Lime-Water by Gas, with vitriolic Acid. Expose this Mixture in a Sand-Heat of about 140° or 150°, and after it has stood in this Situation a Week, or longer, during which Time it has been frequently agitated, add about four Grains of the purest Sea-Salt;—then boil this Mixture in the Flask, or in a Vessel of Silver, so as to separate from it all the Air it contains, and filter it through Paper previously washed by filtering through it hot distilled Water.

Divide this filtered Solution into four equal Parts, one of which must be contained in a Wine-Quart Bottle; to each of these Parts add ¾ of a Quart, or as much as will fill these Quart Bottles, of the above distilled Water, previously boiled in a Florentine Flask or in a clean Silver Vessel, so as to have expelled all the Air dissolved therein (*b*), and agitate a short Time each of these Bottles. Then invert each of these Bottles in a Tub of common hard Pump-Water, and add thereto half an Ounce Measure of a Mixture of one Part of common Air and two Parts of *the Compound of Air and Phlogiston*, (formed by exposing Air

(*b*) If Water free of Air is wished to be kept in Readiness, it should be preserved in Vessels perfectly filled with it, and well corked soon after boiling.

to

to a Mixture of Iron-Filings and Sulphur); then cork the Bottles while inverted, and after Agitation frequently, and preserving them in an inverted Position out of the Water for three Weeks, a Month, or six Weeks, upon withdrawing the Cork from the Bottles inverted in the Tub of Water, the permanent Vapours will be found dissolved or suspended; for Water will rise within the Bottles to occupy the Place of these Substances.

During the Time these Bottles are inverted and uncorked in the Tub of Water as little Motion should be used as possible in order to prevent the Mixture of the Water of the Tub with that of the inverted Bottles.

The Compound of Air and Phlogiston used upon this Occasion should be deprived of Smell and Taste, by repeatedly transferring it through Water.

Unless Care be taken to use distilled Water free of Air the above Quantity of Mixture of permanent Vapour will not be dissolved; and as it is difficult to deprive Water entirely of Air by Exposure a short Time to a boiling Heat the above Proportion of *the Compound of Air and Phlogiston* to the *Air* is greater than that found in Buxton-Water, because it is supposed that the Air will scarcely ever be separated entirely from the distilled Water used upon this Occasion.

In

In this Manner we may compoſe a dilute Solution reſembling Buxton-Water, excepting that as the Heat of the Atmoſphere is rarely equal to the Heat of Buxton-Water, the Temperature of this Spring muſt be communicated by immerſing the above Quart Bottles, after pouring out about a Tea-ſpoonful of the Solution from each, corked in a Veſſel of Water heated to 82° or 84° for a ſufficient Time immediately before drinking it; and as only a Part of one of theſe Bottles will probably be drank at a Time the remaining Solution therein ſhould be either poured into a ſmaller Bottle to fill it quite full and be kept corked, or the Quart Bottle ſhould be kept in a very cool Situation till uſed.

Inſtead of *the Compound of Air and Phlogiſton* employed in compoſing a Mixture reſembling Buxton-Water, if there be an Opportunity it will be much better to uſe the permanent Vapour that extricates itſelf from Buxton-Water.

If diſtilled Water cannot be conveniently obtained, Rain or Snow-Water collected free of Impurities may be believed to anſwer nearly as well.

If we wiſh to exhibit a larger Proportion of the permanent Vapour that ariſes from Buxton-Water than is contained in the above Quantity of Mixture, half an Ounce Meaſure of this permanent Vapour, or of Air united with Phlogiſton by the

the Expoſure of Air to a Mixture of Iron-Filings and Sulphur may be added to the above Compound reſembling Buxton-Water; and although there may not be Water ſufficient to diſſolve this additional Quantity of permanent Vapour, yet by Agitation immediately before drinking it a great Part of it may be ſuſpended therein.

6. As it is highly probable that the medicinal Efficacy of Buxton-Water depends chiefly upon the permanent Vapour that ſeparates ſpontaneouſly; and as this Subſtance is perhaps *the Compound of Air and Phlogiſton*, a new and probably extenſively uſeful, and powerful Article of the *Materia Medica* is pointed out to the Attention of Phyſicians, and in future this permanent Vapour of Buxton-Water, or *the Compound of Air and Phlogiſton*, may be in as frequent Uſe as Gas. For this Purpoſe ſome Perſon ſhould be appointed at Buxton to collect this permanent Vapour (*c*). It will be found moſt convenient to have it contained in ſmall Bottles, as in Phials of two or four Ounce Meaſures, which may be ſent to any Diſtance from Buxton, and uſed at any Time for compoſing artificial Buxton-Water; or even be uſed at Buxton either in the Form of this artificial Buxton-Water (*d*), or mixed only with ſome mucilaginous Subſtance (*e*). This Vapour when

(*c*) P. 23, this Vol.
(*d*) P. 204, ibid.
(*e*) Exp. XVI. p. 60, ibid.

taken

taken into the Stomach in either of theſe Forms will perhaps produce greater Effects than Buxton-Water itſelf, becauſe we can thus apply it in much greater Quantity than by the Uſe of this tepid Water (*f*), and without the Loſs of any efficacious Quality or Subſtance of Buxton-Water. It is well known that the moſt efficacious and generally uſed mineral Waters—*Sea-Water*, and *acidulous Springs*, as *Spaw*, *Pyrmont*, *Driburg* &c.—may be compoſed by Art ſo as to be equal if not ſuperior to the natural Compounds. And as it now appears that the Efficacy of Buxton-Water in Diſeaſes as far as depends upon *Impregnation* (*g*) reſides in the permanent Vapour which eſcapes ſpontaneouſly from the Bath at Buxton, it might be very ſerviceable to the Public if particular *Directions* were publiſhed, ſhewing *the Manner of impregnating Water with the permanent Vapour that extricates itſelf from Buxton-Water; or with a Subſtance reſembling this Vapour—the Compound of Air and Phlogiſton*—in the ſame Manner, or upon the ſame Plan as has been already done by Dr. Prieſtley for the Purpoſe of adminiſtering Gas with more Effect than, by Means of Spaw-Water, Pyrmont-Water, &c. or

(*f*) See P. 152, 153, this Vol.
(*g*) See P. 165, ibid.

where theſe natural Compounds containing it cannot be obtained.

7. This Hiſtory points out pretty certainly, the Occaſion of the *Head-Ach*, *Vertigo*, or *Light-headedneſs*, which is a very common Effect of the internal Uſe of Buxton-Water, namely, the *permanent Vapour* that ſeparates ſpontaneouſly therefrom; and therefore, that this Symptom is not to be conſidered as a Criterion of Gas, when it is occaſioned by drinking a medicinal Water.

This Effect is alſo frequently accompanied with *Heat*, and is produced by the ſame Occaſion.

Theſe two Effects, namely, *Head-Ach*, *Vertigo*, or *Light-headedneſs*, and *Heat*, experienced frequently ſoon after drinking Buxton-Water, may be conſidered as Proofs of this Water poſſeſſing Powers of producing Changes in the human Conſtitution, not found in common Spring-Water of the Temperature of Buxton-Water.

Alſo this Hiſtory will be found uſeful in explaining a Variety of other Effects on the human Body, in a State of Health and Diſeaſe, when theſe Effects ſhall be obſerved and related.

8. The exploding the prevailing erroneous Opinion, that the permanent Vapour that ſeparates itſelf from Buxton-Water is Gas, or fixed Air, may be reckoned amongſt the important Uſes of this Hiſtory.

9. Theſe

9. Thefe Obfervations and Experiments may be, perhaps, not only ufeful to the Art of Phyfic, but to the Arts and Sciences in general; becaufe they make an Addition, although a very fmall one, to the prefent Stock of natural Hiftory, which is the Foundation of all the Arts and Sciences:—In Hiftoria naturali bona, & bene inftituta Claves funt & *Scientiarum* & *Operum*.—*Lord Verulam*.

OBSERVATIONS

Made after the Parts of the preceding Work to which they refer were printed.

Note to Page 167, Line 27, Vol. I.

I Have lately obſerved, that a Spring at Roſington-Bridge, four Miles from Doncaſter, near the London Turnpike-Road, on its being firſt taken from the Spring in a Decanter or Bottle filled therewith, has a peculiar Smell of the fetid or ſulphureous Kind, eſpecially upon Agitation; and has a very ſlight inky Taſte. This Smell and Taſte diſappeared on ſtanding a few Minutes in the open Air. This Water appeared to be rather ſingular, in as much as it did not turn in the leaſt milky or muddy with Lime-Water. It appeared to be alſo of uncommon Purity; for it remained clear and without Sediment after the

Addition of Alkali. It united with Soap without the leaſt Decompoſition; and, by its ſparkling much when placed near the Fire, ſeemed to contain the uſual Quantity of Air. This Spring was uſed for waſhing and brewing, alſo for Tea, and did not fur Veſſels: it boiled Greens ſoft and yellowiſh. It did not tinge poliſhed Silver immerſed in it; nor did it decompoſe upon Expoſure to the Air, or produce Colour with powdered Galls; and it aroſe out of ſome boggy Ground in a ſandy Soil. Other Springs near it were hard, and furred Veſſels during boiling.

Another Spring likewiſe has been mentioned to me, that ſprung out of a Grit-Stone Stratum in a Cellar, that has a Smell of the ſulphureous or fetid Kind, which diſappeared when expoſed to the Air; and was, I believe, a hard Water.

It is a Queſtion whether the fetid Odour in the above Spring-Waters was occaſioned by hepatic Air, or ſome other Vapour.

The Origin of this Vapour alſo is not obvious.

Theſe Springs did not appear to contain any Acid united with Earth, which I have found to be the Caſe whenever there was no calcareous Earth in Water, and I have never found calcareous Earth in Springs without a Quantity of Gypſum.

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Vol. I. p. 55, l. 32.

Black Wadd, Ochra friabilis nigro-fuſca of Da Coſta, p. 102 *, is an Ochre found in the Veins of *Lead-Ore*, eſpecially at *Portaway* Lead-Mine, near Winſter.

" It is not yet known to the Painters, but is greatly worth their Attention. I have tried it both in Water and Oil, in both which it makes a very fine Colour.

This Earth by ſome Experiments made on it is found to be very inflammable, when prepared in a particular Manner. I cannot ſay the Experiment ſucceeded with me, but as it ſucceeded with ſeveral Gentlemen of great Veracity, I cannot omit giving it a Place in my Hiſtory.

The firſt Diſcovery of the inflammable Property of this Earth was made by a Derbyſhire Gentleman, greatly eſteemed for his Knowledge, who publiſhed it in the Gentleman's Magazine for 1752, p. 70, and for 1752, p. 82. The Account is as follows.—" Having powdered and mixed this Ochre with Linſeed-Oil in order to grind for Paint, I left it in a Heap, and returning in about three Quarters of an Hour, found it rolling about in a gentle Flame: the Smoke and Smell made it impoſſible to endure being near it. A ſecond Time I mixed about the ſame

* A natural Hiſtory of Foſſils, by Emanuel Mendes da Coſta, 4to, 1757.

Quantity, i. e. one Pound and a half, to try if it would operate as before; it lay three Quarters of an Hour, and it felt quite cold: but a Smoke aſcending from a Lump the Bigneſs of a Pea, I broke it, and in half a Minute the Whole was on Fire; it did not flame till ſtirred, and then burnt with Violence till the Oil was conſumed."

" By other Experiments made at London, this Earth being mixed with Linſeed-Oil, kindled in a little more than an Hour and a half. It did not flame, but burnt with intenſe Heat for more than three Hours till all the Oil was conſumed, and then it remained to Appearance hardly diminiſhed in Weight or otherwiſe altered in Form or Colour; when ſtirred it emitted a quick Kind of luminous Vapour like bruiſed Gunpowder. Upon mixing of it a ſecond Time, it fired again, though after much longer trying; but on trying it a third Time it did not fire."

This Earth, ſays the Author, " was got in a Lead-Mine in the Peake of Derbyſhire, about ten Fathom below the Earth's Surface; it is there further ſaid, that it lies very deep in the Earth, and that there are Strata of it from one Inch to ten or twelve Inches thick, eſpecially at Parwick, which is four Miles North-weſt from Aſhbourn; and at Elton, which is eight Miles North-weſt from Aſhbourn; that it is uſed in Derbyſhire as Paint, particularly to mix with other Colours, to make them dry (where the Colour will admit of

ſuch

fuch a Mixture), as Chocolate Colour, Mahogany Colour, or other Colours for Priming, &c *."

I have to add, that fince the above Account was written this Subftance has been, I am informed, much ufed by Painters, on Account of its being a *quick Drier*.

The Refult of an Affay of Black Wadd by an able Chymift was, I am told, that it confifts of Manganefe, Lead-Ore, Iron, and an Earth.

Its Property of burning in the Heat of the Atmofphere was difcovered by Mr. Richard Roe of Derby, Houfe-Painter, upwards of 30 Years ago.

In fome Experiments lately made in London, under the Direction of feveral very ingenious and refpectable Philofophers, this Ochre inflamed in about 50 Minutes in every Inftance. No Attention was paid to the Proportion of Oil and this Ochre.

In order to afford fome Light for the Explanation of this Property of Black Wadd I fhall obferve, that Linfeed-Oil and Lamp-Black mixed together form a Mixture which has been lately found to inflame fpontaneoufly upon Expofure to the Atmofphere, as was difcovered accidentally by the taking Fire of a Frigate the 20th April, 1779. Mr. Georgi's Experiments, lately, fhew, that Hemp and Flax take Fire fpontaneoufly †.

* Da Cofta's Hiftory of Foffils, 4to. p. 102.

† *Acta Academiæ Scientiarum Imperialis petropolitanæ* for 1779.

The

The spontaneous Inflammation of Iron Pyrites, and of Sulphur and Iron mixed together, has been long known.

Vol. I. p. 106.

I have the Satisfaction of finding, that the Opinion I ventured to deliver concerning the Use of nitrous Gas as a Test of the *Purity* and *Salubrity* of the Atmosphere of different Regions has been fully justified in a Paper * lately written and published by one of the most respectable Authorities in Philosophy; as will appear from the following Extracts. These, I trust, cannot but be acceptable to many of my Readers, independently of their serving to establish the Truth of my Remarks on the above Subject.

Among other Sources of Error in estimating the State of atmospheric Air by Means of nitrous Gas, the Author of the Memoir above alluded to particularly mentions the Nature of the Water in which the Mixture is made.

" This Difference in the Diminution according to the Nature of the Water is a very great Inconvenience, and seems to be the chief Cause of Uncertainty in trying the Purity of Air; —

It shews plainly, how little all the Experiments

* An Account of a new Eudiometer by Mr. Cavendish.— Phil. Trans. Vol. LXXIII. Part I. 1783.

which

which have hitherto been made for determining the Variations in the Purity of the Atmoſphere can be relied on, as I do not know that any one before has been attentive to the Nature of the Water he has uſed, and the Difference proceeding from the Difference of Waters is much greater than any I have yet found in the Purity of Air.—

— — — — — — — — — —

— — — — — — — — — —

During the laſt half of the Year 1781, I tried the Air of near ſixty different Days in order to find whether it was ſenſibly more phlogiſticated at one Time than another; but found no Difference that I could be ſure of, though the Wind and Weather of thoſe Days were very various; ſome of them being very fair and clear, others very wet, and others very foggy.

My way was to fill Bottles with Glaſs Stoppers every now and then with Air from without Doors, and preſerve them ſtopped and inverted into Water, till I had got ſeven or eight, and then take their Teſt; and whenever I obſerved their Teſt I filled two Bottles, one of which was tried that Day, and the other was kept till the next Time of trying, in order to ſee how nearly the Teſt of the ſame Air, tried on different Days, would agree. The Experiment was always made with diſtilled Water, and Care was always taken to obſerve the Diminution which nitrous Air ſuffered by being ſhaken in the Water as above-mention-

ed. The Heat of the Water of the Tub was commonly ſet down.

The Reſult was that the Teſt of the different Bottles tried on the ſame Day never differed more than .013, and in general not more than half that Quantity. The Teſt, indeed, of thoſe tried on different Days differed rather more; for taking a Mean between the Teſts of the Bottles tried on the ſame Day, there were two of thoſe Means which differed .025 from each other; but, except thoſe two, there were none which differed more than .013. Though this Difference is but ſmall, yet as each of theſe Means is the Mean of ſeven or eight Trials, it is greater than can be expected to proceed from the uſual Errors of the Experiment. This Difference alſo is not much diminiſhed by correcting the Obſervations on Account of the Heat and abſorbing Power of the Water, according to a Rule above given. This might incline one to think, that the Parcels of Air examined on ſome of thoſe Days of Trial were really more dephlogiſticated than the Reſt; but yet I believe that they were not: for whenever there was any conſiderable Difference between the Means of two ſucceſſive Days of Trial, there was nearly the ſame Difference between the Teſts of the two Bottles of the very ſame Air tried on thoſe two Days. For Example, the Mean of the Trials on July 7, was .016 leſs than that of thoſe on the 15th Day of the ſame Month;

but

but then the Teſt of the Air caught and tried on the 7th was equally leſs than that of the Air of the ſame Day tried on the 15th; which ſhews that this Difference between the Means of thoſe two Days was not owing to the Parcels of Air tried on the former Day being really more dephlogiſticated than thoſe tried on the latter, but only to ſome unperceived Difference in the Manner of trying the Experiment; or elſe to ſome unknown Difference in the Nature of the Water or nitrous Air employed. —

On the Whole, there is great Reaſon to think, that the Air was in Reality not ſenſibly more dephlogiſticated on any one of the ſixty Days on which I tried it, than the reſt.

The higheſt Teſt I ever obſerved was 1.100, the loweſt 1.068, the Mean 1.082.

I would by all Means recommend it to thoſe who deſire to compare the Air of different Places and Seaſons, to fill Bottles with the Air of thoſe Places, and to try them at the ſame Time and Place, rather than to try them at the Time they were filled, as all the Errors to which this Experiment is liable, as well as thoſe which proceed from a Difference in the Nature of the Water and nitrous Air, will commonly be much leſs when the different Parcels of Air are tried at the ſame Time and Place than at different ones; provided

might proceed from the Error of the Experiment; and by taking a Mean of all, there did not appear to be any Difference between them. The Number of Days compared was 20, and a great Part of them taken in Winter, when there is a great Number of Fires, and on Days when there was very little Wind to blow away the Smoke. — — — — — — — —
— — — — — — — — — —
— — — — — — — — — —

When the Impurities mixed with the Air have any confiderable Smell, our Senfe of Smelling may be able to difcover them, though the Quantity is vaftly too fmall to phlogifticate the Air in fuch a Degree as to be perceived by the nitrous Teft, even though thefe Impurities impart their Phlogifton to the Air very freely. For Inftance, the great and inftantaneous Power of nitrous Air in phlogifticating common Air is well known; and yet ten Ounce Meafures of nitrous Air, mixed with the Air of a Room upwards of 12 Feet each Way, is fufficient to communicate a ftrong Smell to it, though its Effect in phlogiftcating the Air muft be utterly infenfible to the niceft Eudiometer; for that Quantity of nitrous Air is not more than the 140,000th Part of the Air of the Room, and therefore can hardly alter its Teft by more than $\frac{3}{140000}$ or $\frac{1}{147000}$ Part. Liver of Sulphur alfo phlogifticates the Air very freely, and yet the Air of a Room will acquire a very

ftrong

vided only, that Air can be kept in this Manner a ſufficient Time without being injured, which I believe it may, if the Bottles are pretty large, and Care is taken that they, as well as the Water uſed in filling them with Air, are perfectly clean. I have tried Air kept in the above-mentioned Manner for upwards of three Quarters of a Year in Bottles holding about a Pint, which I have no Reaſon to think was at all injured; but then I have tried ſome kept not more than one-third Part of that Time, which ſeemed to have been a little impaired, though I do not know what it could be owing to, unleſs it was that the Bottles were ſmaller, namely, holding leſs than one-fourth of a Pint, and that in all of them, except two, which were ſmaller than the reſt, the Stopper which, however, fitted very tight, was tied down by a Piece of Bladder.

I made ſome Experiments to try whether the Air was ſenſibly more dephlogiſticated at one Time of the Day than another, but could not find any Difference. I alſo made ſeveral Trials with a View to examine whether there was any Difference between the Air of London and the Country, by filling Bottles with Air on the ſame Day, and nearly at the ſame Hour, at Marlborough-Street and at Kenſington. The Reſult was, that ſometimes the Air of London appeared rather the pureſt, and ſometimes that of Kenſington; but the Difference was never more than

might

ſtrong Smell from a Quantity of it vaſtly too ſmall to phlogiſticate it in any ſenſible Degree. In like Manner it is certain, that putrifying animal and vegetable Subſtances, Paint mixed with Oil, and Flowers, have a very great Tendency to phlogiſticate Air; and yet it has been found, that the Air of an Houſe of Office, of a freſh painted Room, and of a Room in which ſuch a Number of Flowers were kept as to be very diſagreeable to many Perſons, was not ſenſibly more phlogiſticated than common Air. There is no Reaſon to ſuppoſe from theſe Inſtances, either that theſe Subſtances have not much Tendency to phlogiſticate the Air, or that nitrous Air is not a true Teſt of its Phlogiſtication, as both theſe Points have been ſufficiently proved by Experiment. It only ſhews, that our Senſe of Smelling can, in many Caſes, perceive infinitely ſmaller Alterations in the Purity of the Air than can be perceived by the nitrous Teſt, and that in moſt Rooms the Air is ſo frequently changed that a conſiderable Quantity of phlogiſticating Materials may be kept in them without ſenſibly impairing the Air. But it muſt be obſerved, that the nitrous Teſt ſhews the Degree of Phlogiſtication of Air, and that only; whereas, our Senſe of Smelling cannot be conſidered as any Teſt of its Phlogiſtication, as there are many Ways of phlogiſticating Air without imparting much Smell to it; and I believe there are many ſtrong-ſmelling Subſtances which do not ſenſibly phlogiſticate it.

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Phoſphorus not only ſeems to *unite* with any Kind of permanent Vapour, excepting Air, and form a Compound that burns in the ordinary Heat of the Atmoſphere, during which it produces Flame, but alſo either combines or mixes with other Things, with which it forms Mixtures that burn rapidly, in the Space of a few Seconds of Time, after Expoſure to the Atmoſphere.

I have lately ſeen a Compound of this Sort which was formed of Butter or Oil of Wax, Sulphur, and Phoſphorus of Urine, but I do not know the exact Proportions of theſe Subſtances in this Mixture, nor with Certainty the Manner of mixing them together; and if any Perſon ſhould attempt to compoſe this Mixture he muſt remember, that it will break out into a Flame, and burn furiouſly while it is compoſing, unleſs certain Circumſtances be preſent to prevent the Inflammation. Thoſe who are acquainted with the Principles of Inflammation will readily conceive various Circumſtances that would prevent the Combuſtion of this Subſtance while it is forming—what thoſe are already attended to, in making this Mixture, I do not know. It is clear that the burning of this Subſtance may be prevented, by firſt mixing the Butter of Wax in a fluid State with the Flowers of Sulphur—perhaps, with one-third of its Weight of this Subſtance—in a

ſmall Phial, or other Veſſel, filled with phlogiſticated Air, or any other permanent Vapour excepting Air; and then adding the Phoſphorus of Urine in a very ſmall Proportion—perhaps, one-hundredth of the Weight of the other two Subſtances—ſo as to avoid the Acceſs of the atmoſpheric Air to the Vapour in the Veſſel containing the Mixture.

The Veſſel containing theſe Subſtances ſhould then be expoſed to a gentle Heat, ſufficient to melt the Phoſphorus, which by Agitation may be mixed with the other Subſtances. The Mouth of the Veſſel containing this Compoſition muſt be kept cloſed, ſo as to prevent the Introduction of atmoſpheric Air.

This Compound on mere Expoſure to the Atmoſphere, eſpecially if previouſly warmed a little by holding the Phial containing it in the Hand, burns as rapidly as Oil does when ſet on Fire by Heat.

On Account of this Property of ſpontaneous Inflammation, if the End of a thin Piece of dried Fir-wood, or a Match of Paper be dipped into this Mixture it will ſmoke immediately upon withdrawing it from the Bottle, and in a few Seconds will burſt into a Flame and ſet the Paper or Wood on Fire.

It is ſufficiently obvious that this Compound may be applied to many very uſeful as well as moſt miſchievous Purpoſes. It may be very conve-

conveniently used for the Production of Light, and the setting on Fire other Substances.

If pretty large Glass Vessels, as Florence Flasks, nearly filled with this Substance be thrown so as to break to Pieces upon or near various Things, as Ships, certain Buildings, &c. the Destruction of such Structures by Fire may be effected by this Means.

Matches which burn upon Exposure to the Air may be made of this Substance, by including them in Tubes filled with any permanent Vapour but Air.

The phosphoric Matches now in common Use are said to be made of a Mixture of Phosphorus and Oil of Cloves; and, probably, Phosphorus and any essential Oil mixed together form a Compound that burns rapidly, and flames immediately, or in a few Seconds of Time, after Exposure to the Atmosphere.

I N D E X.

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F I N I S.

E R R A T A.

Vol. I. Page 52, Line 5, for *contains*, read, *contain*.

P. 70, l. 29, for *mild, fine, and very warm*, read, *fine* and *temperate*.

P. 72, l. 2, for, *commonly many Vegetables produced in Gardens*, read, *many Vegetables produced commonly in Gardens*.

P. 115, l. 2, for, *Exper. XLI. XLII. of this Work*, read, *Exper. XLV. XLVI. p.* 149, *Vol. II.*

P. 131, l. 17, for, 144, read, 124.

P. 140, l. 14, dele Comma after Grit-Stone.

P. 144, l. 3, add after Buxton, *or to ſpeak more accurately, the Streams of the ſubterraneous tepid Springs*.

Ibid. l. 8. for, *Manner deſcribed p.* 9, read, *Manner as deſcribed, p.* 11, 12.

P. 172, l. 16, add a Comma after *much leſs*.

P. 176, l. 24, dele Comma after *Gas*.

P. 179, l. 8, add a Comma after Lectures.

P. 180, l. 15, dele Comma after *left*.

P. 194, l. 30, —— *Mixture*.

P. 207, l. 9, —— Comma after *Acid*.

P. 208, l. 25, for 30, read 15.

P. 216, Note (*a*), l. 1, dele Comma after *Cavallo* and *Prieſtley*.

Ibid. l. 3, dele Comma after *Gas*.

Ibid. l. 3, for *does*, read *did*.

Ibid. l. 8, for, *decompoſed Soap impregnated with Gas*, read, *impregnated with Gas decompoſed Soap*.

P. 250, l. 3. for *one Meaſure*, read, *two Meaſures*.

Ibid. l. 20, for *one Meaſure*, read, *four Meaſures*.

P. 253, l. 18, for *is*, read, *are*.

Ibid. l. 23, for *its*, read, *their*.

P. 272, l. 8, for *Meaſuers*, read, *Meaſures*.

P. 307, l. 23, note (*m*), for *a Drachm*, read, 100 *Grains*.

P. 310, l. 17, dele *Excluſive of the Quantity contained in calcareous Earth in the Heat of boiling Water*.

Vol. II. P. 21, l. 5, for *confidentially*, read, *confidently*.

P. 56, l. 11, for *one*, read, *one Ounce*.

P. 96, l. 16, for *thirty-ſixth's*, read, *thirty-ſixths*.

P. 146, l. 27, for *Cyathi*, read, *Cyani*.

P. 177, l. 14, for *only and firſt*, read, *firſt and only*.

P. 179, l. 29, for *was*, read, *were*,

P. 184, l. 3, for, *which is leſs than one two hundred and ſixty thouſand million*, read, *which is leſs than one two thouſand ſix hundred millionth*.

P. 185, l. 6, for *alſo*, read *likewiſe*.

P. 198, l. 26, for *which are*, read, *which were*.